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Some Electro-Chemical Centres

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Some Electro-Chemical Centres

A REPORT

To the Electors of the Gartside Scholarships

BY

J. N. PRING, M.Sc.

Gartside Scholar

MANCHESTER
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THE GARTSIDE REPORTS.

THE Gartside Reports are the reports made by the Gartside Scholars at the University of Manchester. The Gartside Scholarships were established in 1902 for a limited period, by John Henry Gartside, Esq., of Manchester. They are tenable for two years and about three are awarded each year. They are open to males of British nationality who at the date of the election shall be over the age of eighteen years and under the age of twenty-three years.

Every scholar must enter the University of Manchester for one Session for a course of study approved by the electors. The remainder of the time covered by the Scholarship must be devoted to the examination of subjects bearing upon Commerce or Industry in Germany or Switzerland, or in the United States of America, or partly in one of the above-mentioned countries and partly in others, but the electors may on special grounds allow part of this period of the tenure of the Scholarship to be spent in study and travel in some other country or countries. It is intended that each scholar shall select some industry, or part of an industry, or some business, for examination, and investigate this comparatively in the United Kingdom and abroad. The first year's work at the University of Manchester is designed to prepare the student for this investigation, and it partly takes the form of directed study, from publications and by direct investigation, of English conditions with regard to the industrial or commercial subjects upon which research will be made abroad in the second year of the scholarship. Finally, each scholar must present a report, which will as a rule be published.

The value of a Scholarship is about £80 a year for the time spent in England, £150 a year for time spent on the Continent of Europe, and about £250 a year for time spent in America.

PREFACE.

THE following report is based principally on information acquired during visits to several countries on the Continent of Europe and to the United States and Canada, including British Columbia, during the years 1907 and 1908.

Though the electro-chemical industry is developing rapidly in many directions, the various works in this field are yet comparatively few in number and are located in widely scattered centres. For this reason, a comprehensive survey of the subject is made rather difficult. Moreover, the majority of electro-chemical works are still in a more or less experimental state, and the details of the processes are usually held in strict secrecy so that admittance is, in many cases, very difficult and often quite impossible to obtain by outsiders.

The developments of this industry, however, are well recorded in several important publications, the chief journal of this kind being the "Electro-chemical and Metallurgical Industry" (New York).

In the compiling of this report I wish to acknowledge my indebtedness to Dr. R. S. Hutton for his kind assistance throughout and for furnishing me with valuable introductions in the United States to the leading people of academic and industrial electro-chemistry, who gave me much information and kindly extended several opportunities for inspecting works. In this connection, I have specially to thank Prof. J. W. Richards, Prof. W. D. Bancroft, Prof. S. A. Tucker, Mr. E. R. Taylor, Dr. E. F. Roeber, Dr. H. N. Potter, Mr. T. A. Edison, Mr. E. A. Sperry, and Mr. G. C.

Stone, in the States; Mr. W. H. Aldridge in British Columbia; Major Stassano, of Turin; and Mr. Schneller, of Harlem.

The statistics and data given in this volume have been chiefly collected from existing publications, reference to which is usually given, without further acknowledgment.

Finally, I desire to record my sincere appreciation of the guidance and help I have received from Prof. S. J. Chapman, Dean of the Faculty of Economics, who not only placed me in a position of forming some judgment of the economic side of the question, but has throughout tendered me every encouragement and assistance.

CONTENTS.

INTRODUCTION

THE electro-chemical industry is of comparatively recent origin, since it is only within the last 20 years that it has been possible to employ economically electric energy on a sufficiently extensive scale. The rapid progress which has been noticeable in recent years has gone hand in hand with the general advance in electrical engineering.

When electro-chemical processes were first exploited, great difficulties were met with in obtaining the requisite dynamos and other electrical machinery. Thus, so recently as 1887, at the time of the installation of the Cowles plant for the manufacture of alluminium-alloys at Milton, in Staffordshire, the 500 horse-power dynamo which was specially constructed for this process, was considered so great an achievement that it was for some time known as the "Colossus", whereas to-day 10,000 H.P. generators are in quite common use at large power stations.

The whole scope of applied electro-chemistry has thus constantly expanded with the general developments in electrical engineering and particularly with the cheapening in the cost of power generation resulting from such advances.

Since these early days, the electro-chemical industries have developed along very many different lines, and, indeed, few chemical processes have escaped being affected in a greater or less degree by the application of electrical methods.

In examining the distribution of electro-chemical works, it is very apparent on how many factors the question of the location of an industry depends. One has to consider chiefly the proximity of the market and

of the sources of the raw material, the availability of means of transportation, and the facilities for obtaining labour and power. Another desideratum is the vicinity of subsidiary industries, which facilitate co-operation and, either by serving as a source of materials used in the electro-chemical process, or by offering an outlet for the products of the factory, give valuable economic assistance.

In most cases it is found that electro-chemical works gather around centres where cheap power is available. This is due to the fact that in the majority of these processes, the consumption of power is very great, and the outlay for this amounts to a very large proportion of the total working expenses. Another reason is probably to be found in the fact that the supply of power from an independent source, instead of generating it inside the factory, saves the individual company a large capital outlay; and as electro-chemical enterprises have frequently to fight their way against outside interests, a saving in this capitalisation is often imperative.

In this country no revolution has been caused in the chemical industry by the introduction of electro-chemical methods. The open competition of old established and well developed methods makes the introduction of new processes a very slow matter, and even in the case of commodities which can only be prepared by electro-chemical means, it appears to be more economical to import these from countries like America where conditions are especially favourable for the development of new processes.

In America the electro-chemical industry has made very rapid strides. Untrammelled by the existence at home of chemical works on a sufficiently extensive scale to provide the rapidly growing demands, the newer processes have here found a very suitable locality for their development, and during their infancy enjoy the fostering influence of a protective tariff. The progress in

America is also due in no small measure to the great enterprise and superior technical training of the people.

The existence of cheap water power may, in some few cases, be imperative, and in others, advantageous for the successful carrying on of electro-chemical processes, but the relative power expenditure varies so greatly from case to case that what is true of one product by no means holds good for another. Gas and even steam power, as will be shown later, frequently afford greater general economy.

It is largely from these considerations that a study of the economics of the electro-chemical industries individually, possesses a growing interest in our own country, and there can be no doubt that in the near future many of these processes will undergo substantial development in Great Britain.

CHAPTER I.

COST OF POWER PRODUCTION.

THE question of the cost of power production is a very intricate one on account of the number of factors which have to be considered in this computation. In many cases the figures quoted have been vaguely and erroneously estimated, either from interested motives or through misunderstanding of some of the elements which build up the total cost.

Even with all data at hand, the calculation of power cost certainly becomes an involved problem.

The total cost of generating power by any means consists of two portions:—

(1) The "works costs," which include such items as fuel, oil, water, etc., and their conveyance, and the expenses of management, attendance, and accessory duties.

(2) "Capital costs," which embrace the interest on the outlay on machinery and buildings, together with an adequate provision for the depreciation of plant, and also the rent of the land.

These elements of cost are necessarily very variable, depending on the locality, size of plant, perfection of machinery, and cost of fuel and labour, and are continually being lowered through the refinement of methods and improvement of machinery.

In the case of gas engines, the working cost is low owing to the high thermal efficiency, though the capital cost is higher than for a steam turbine plant owing to the heavier initial expense. With water power, the capital expenditure constitutes the bulk of the total cost

on account of the expense of development and the fact that no fuel is required.

Conclusions as to the cost of power are apt to be hastily drawn from the results obtained by electric lighting and power companies, although these are so very different in character from those engaged in continuous power generation on a large scale, which latter alone are of real interest in dealing with this question.

It must be remembered that the load factor, or the ratio of the average power to the maximum consumed, is of great importance in determining the cost. Thus, in the case of companies which supply electric current for lighting and power purposes, a load factor of over 50 per cent. is very rarely obtained, whereas with purely electro-chemical processes this will usually reach as high a value as 95 per cent.

Steam Power.

The following table* contains estimates of power costs at several large stations in this country where steam power is used :—

COST OF POWER GENERATION. STEAM. WORKS COSTS PER B.T.U.

Station	Coal Per ton s.	d.	Coal Per unit d.	Wages d.	Water Oil Stores d.	Repairs, etc. d.	Total per unit d.
Newcastle (Carville)	5	6	0·078	0·022	0·004	0·016	0·121
Sheffield (Neepsend)	5	8	0·096	0·072	0·003	0·038	0·209
Messrs. Watson (Linwood)	8	0	0·148	0·022	0·013	0·022	0·205

CAPITAL COSTS.

	Per unit d.
10 per cent. depreciation on £15 per kilowatt ...	0·042
5 per cent. interest „ „ ...	0·021
	0·063

* R. S. Hutton. *Engineering* (Dec. 7th, 1906), vol. lxxxii, p. 779.

CONVERSION TABLE.

Cost per B.T.U. to cost per H.P. and K.W. year.

B.T.U.	H.P. year	K.W. year
d.	£	£
1·0	27·4	36·5
0·5	13·7	18·25
0·2	5·5	7·3
0·1	2·74	3·65

1 H.P. = ·76 K.W.

Gas Engines.

Much may now be expected from the development of large gas engines worked in conjunction with producer or blast furnace gas, and, especially in the latter case, it seems highly probable that use may be made in the future of power generated in this manner for the production of ferro-alloys and steel, which themselves are so closely associated with the application of the metallurgical products of the blast furnace.

An estimate of power costs in the case of gas engines is as follows:—*

For a power house generating 20,000 H.P. with a load factor of 95 per cent., using blast furnace gas, assumed to be obtained free of cost, the total capital cost of machinery and buildings per brake horse power is computed at £10. 13s., and the total cost per H.P. year, including interest on capital, labour, repairs and depreciation of plant is variously fixed at £1. 14s. 4d., £1. 17s. 4d., and £2. 1s. 10d., according to whether the life of the plant is assumed at 20, 15, or 10 years. In the case of producer gas, obtained from coal, and allowing for the value of ammonia recovered, the estimated cost of power is as shown in the table:—

Price of Coal per ton: 6s.	7s. 6d.	9s.		Life of Plant
£2 1 9	£2 8 5	£2 15 1	...	20 years
2 6 0	2 12 8	2 19 4	...	15 years
2 10 3	2 16 11	3 3 7	...	10 years

* J. J. Robinson. *Mech. Engineer* (April 3rd, 1908), vol. xxi, p. 436.

This estimate appears to be too low, though on the other hand an important calculation made by C. E. Lucke* of power costs in the States is probably too high. The latter deals with oil and gas engines, and steam and water power, and the results are as follow :—

	Water Power	Oil Engines	Gas Engines and Producer	Steam Engines
First cost per K.W.	$75·00–200·00	160 K.W. units $217·00	600 K.W. $270·00	5000 K.W. $110·00–150·00
Fixed charges rate per cent.	10%	10%	10%	10%
Fixed charges per K.W. year	$7·50–20·00	$21·70	$27·00	$16·50–22·50
Operating and Mfg. costs per K.W. year	1·00–5·00	56·94	38·54	52·56
Total power costs per K.W. year	8·50–25·00	78·64	65·54	69·00–75·00

Water Power.

The cost of water power varies within very wide limits, and in some instances descends to an exceedingly low figure. In other cases, however, water powers have been developed at an expense which brings the cost of supply almost to the level of that of steam power. In the case of the most important water power companies there is usually no information published with regard to costs. Large profits are frequently made, and the price is in a large degree adjusted in accordance with the demands of the individual consumers. The following examples will serve to show the wide variations which exist in individual cases. Examples marked with an

* C. E. Lucke. *Electrochem. and Metall. Ind.* (1907), vol. vi, p. 230.

asterisk represent prices at which the power is actually sold :—

Water Power.

Total costs or charges per Electrical H.P. year to large consumers.

	Cost £ s. d. £ s. d.	Remarks
Niagara*	3 10 0—4 3 0	
Niagara* (Ontario Power Company, to municipalities)	2 2 6	
Niagara* (Power delivered to City of Toronto) ...	2 17 9	
Sault Ste. Marie*... ...	2 1 6	
Cameron Rapids, Ontario	1 17 3	Total generating and transmitting costs allowing interest at 5 per cent.
Montreal*...	3 3 0	
Kootenay Power Co., B.C. .	5 0 0	
Mexico*(El Oro Gold Mines)	10 0 0	
Kanawha Falls (Va.) ...	2 0 0	
Horahora Rapids (New Zealand	3 0 0	Proposal of Waihi Gold Mining Co. No transmission costs included.
Svaelgfos, Norway ...	0 8 3	
Notodden, Norway ...	0 13 7	
Sweden	0 13 0—1 10 0	
Austria (Meran)*... ...	2 7 6	
Savoy (Bellegarde)* ...	2 4 0	
Savoy (Chedde)	0 18 4	
Tivoli (Italy)	3 0 0	Delivered in Rome.

ESTIMATED CAPITAL COST OF HYDRO-ELECTRIC POWER STATIONS.

Situation	Power Proposed or Installed	Total Cost £	Cost per H.P. Installed £	s.	d.
Lake Titicaca, Peru ...	2,000,000	8,000,000	4	0	0
Mexican Light and Power Co.	48,000	417,000	8	14	0
Cameron Rapids, Ontario ...	16,350	168,300	10	6	0
Augst-Wyhlen, near Rheinfelden, Basle	30,000	360,000	12	0	0
Societa Idroelettrica, Ligure, Milan	45,000	600,000	13	4	0
Aveto Riva	—	—	14	13	0
Societa Generale Elettrica Adamello, Milan	30,000	400,000	13	6	8
Horahora Rapids, Waihi, New Zealand	4,000	70,000	17	10	0
Turin	8,000	231,700	28	19	0
	(including transmission lines)				

Mech. Engineer, March 27th, 1908. XXI.

The importance of this question of the cost of power in electro-chemical operations varies very much from case to case according to the proportion the power-costs bear to other operating expenses and to the value of the product. The data available for individual cases are somewhat scanty.

The following table serves to exhibit roughly the wide differences which exist in some of the principal electro-chemical industries:—

Product	Yield per H.P. year in tons	Approx. Value per ton
Copper (refined)	15 to 24	£58
Caustic Soda...	1·4 to 2·4 (75 per cent) also 3 to 5 Bleaching Powder.	£10 (caustic soda)
Potassium Chlorate	0·5 to 0·8	£32
Calcium Carbide	1·2 to 2·0	£13
Ferro Chromium (70 per cent. Cr.)	0·8	£45
Aluminium	0·25	£110
Pig Iron (from Ore)... ...	2—4	£3. 5s.
Steel (from Pig and Scrap)...	10	—
Lead (Bett's process) ...	60	£15

CHAPTER II.

NIAGARA FALLS.

THE Niagara River, in its 25 miles course between Lakes Erie and Ontario, has a change of level of 326 feet, including a sheer drop of 165 feet at the Falls. The energy obtainable from the Niagara River has been estimated at 7,000,000 H.P., and since its recognition by engineers as a possible source of power, many schemes for utilising it in large quantities have been put into practice.

At first, some hesitancy was felt since coal was very cheap in this district (7s. a ton), and there was great uncertainty of being able to dispose of the power in such large quantities, but the optimism of the promoters in erecting very large plants has been more than justified; the demand for power continually increases, and is indeed greater than the development of supply. As a result of recent exhaustive international enquiry the development of 750,000 H.P. has been fixed as a limit by the American and Canadian Governments with a view to preventing serious damage to the beauty of the Falls.

At present the following are the most important of the power companies, a total of about 300,000 H.P. being actually monopolised, so that only a small percentage of the total flow of water has been diverted :—

	Power Developed at end of 1906 H.P.	Additional Power development in course of construction H.P.
U.S.A.		
Hydraulic Power and Manufacturing Co.	34,000	100,000
Niagara Power Co. ...	110,000	—
CANADA.		
Canadian Niagara Power Co.	50,000	60,000
Ontario Power Co.... ...	42,000	140,000
Electrical Development Co. of Ontario	10 000	100,000
Total	248,500	397,500

Hydraulic Power and Manufacturing Co.

The oldest power project at Niagara Falls was that of the Hydraulic Power and Manufacturing Co., which was incorporated as early as 1853, and steps were then taken for the construction of a canal 70 feet wide by 10 feet deep, which was finally accomplished after many delays and which has lately been enlarged to a width of 100 feet and a depth of 14 feet. In 1881, power was first supplied for commercial purposes, in 1885, 10,000 H.P. was in use, and in 1896 the erection of a second power house was undertaken. The latter is situated in the gorge below the Falls, an available head of 210 feet being thus obtained. The plant has on several occasions been enlarged, and at the present time there are in operation in this power house 15 turbines, giving a combined output of 34,000 H.P. The electrical development of this company has been made to suit the different industries which have located themselves close to the power house, continuous and alternating current being generated at voltages suitable for the requirements of the consumers.

The Niagara Falls Hydraulic Power and Manufacturing Co. has now erected an additional power house with a capacity of 100,000 H.P., the water being taken from the same canal.

There are separate penstocks to supply water to every 8,000 H.P. turbine. These turbines are of the horizontal shaft type, and will run at 300 revolutions per minute, the alternators directly coupled to the turbines giving 3 phase current at 11,000 volts 25 cycles.

Niagara Falls Power Co.

In 1890, plans for Niagara power development began to meet with more general consideration, and the question of the construction of a large central station was discussed in detail. The project involved the establishment and development of an industrial centre

and concerned itself with the erection of a large power house and the distribution of power to distant towns.

The leading American engineers and capitalists interested themselves in this proposition, though little experience was at hand on which plans could be based. "The Cataract Construction Company" was formed in 1889, and the President, Mr. E. D. Adams, in 1890, established at London an International Niagara Commission with power to award large prizes.

Inquiries and examinations concerning the best known existing hydraulic developments were undertaken, and plans concerning turbines and other machinery incident to the use of water power and its transmission, were submitted to the Commission. The Commission consisted of Lord Kelvin, Dr. Coleman Sellers, Colonel Turrettine, Prof. E. Mascart, and Prof. W. C. Unwin; Prof. George Forbes, of London, served as the company's chief electrical engineer. Rights to develop 200,000 H.P. on the American side were obtained, and the construction of a tunnel was commenced. The erection of the power house was begun in 1891, a short canal being made for this purpose at a point about one mile above the Falls. Two power houses are now situated on opposite sides of the canal, and the water, after passing through iron gratings to remove any debris or ice, is led through penstocks and thence vertically downwards, a distance of 178 feet, to the turbines. The turbines are installed near the bottom of two wheel slots, excavated out of solid rock, under the respective power houses.

After giving up its energy to the turbines, the water is discharged into a tunnel about 21 feet in diameter, and 7,000 feet in length, which carries the water under the city to the lower river. Each turbine is connected by a vertical shaft to an electric generator installed above on the ground level. The two power houses together contain 21 vertical shaft turbines, each turbine being

directly connected to a 2 phase alternator giving 22,000 volts at 25 cycles, operating at a speed of 250 revolutions per minute, and generating 5,000 H.P., making a total capacity for the two plants of 105,000 E.H.P.

The flow of water on to the turbines is controlled by a special form of governor, which is of the pendulum type, and works in conjunction with a relay cylinder. By this means a speed constant to within 1 per cent., is automatically maintained, when variations in load occur.

There are three separate systems of transmission from the power station. Firstly, there is the local transmission of 2 phase current at 2,200 volts as generated, and conveyed entirely by underground cables; secondly, for intermediate distances the current is stepped up to 11,000 volts, 3 phase, and transmitted, first by underground cables, and then by overhead conductors to a transformer station about two miles from the power house, where it is re-converted to 2,200 volts, 2 phase. Long distance transmission, such as to Buffalo, about 18 miles distant, Tonawanda and Lockport, 35 miles distant, is effected by 3 phase current at 22,000 volts along bare overhead conductors.

There are three complete circuits to Buffalo, two of copper and one of aluminium, and the loss amounts to about 10 per cent. when 30,000 H.P. is transmitted. One of the circuits is always in reserve.

After the completion of the second American power house in 1902, a further intallation was commenced on the Canadian side by the same company, operating under the title of the Canadian Niagara Power Co. This plant is situated a short distance above the Horse Shoe Falls, and is in most respects similar in equipment to the older power houses, but the units are here 10,000

H.P. machines, and have a total developed capacity of 50,000 H.P. with an additional 60,000 H.P. in course of installation.

The two plants of the Niagara Power Co. are interconnected by heavy copper cables, so that when necessary, the two stations can run in parallel for the supply either on the American or on the Canadian side.

Largely owing to the financial success of these enterprises, within the last few years several independent companies have come into the field and have installed large hydraulic power stations on the Canadian side of the Falls.

The Electrical Development Co. of Ontario.

This company was organised at Toronto by a syndicate with Colonel Pellatt as President, for the purpose of transmitting power to that city and other places in Ontario. In 1903 rights were obtained for the purpose of generating electricity to the extent of 125,000 H.P., and a site was chosen and secured for the location of the power plant. The company also purchased a right of way 78 miles in length between Niagara Falls and Toronto, and 530 acres of land about two miles from the Falls and fronting on the Chippewa River, which communicates with the Welland Canal, and here it is expected that industrial plants will be established. The power house has been erected at Tempest Point, about half a mile above the Falls. The river has here a rapid drop, and a coffer dam was, with great difficulty, constructed to divert the water toward the power house, and thus raise the level of the water within the dam about 18 feet. The power house is 500 feet long and of handsome architectural design; it will ultimately contain 11 generators, each of 10,000 H.P.

In order to get rid of the tail water a tunnel was made

under the upper rapids, terminating in the face of the Horseshoe Fall, about midway between the Canadian and American banks. This power station was opened on November 19th, 1906, when the first unit was brought into operation and 10,000 horse power generated and transmitted to Toronto.

Ontario Power Company.

The third power plant on the Canadian side is that of the Ontario Power Co., which is at present generating 42,000 H.P. This power house is situated in the gorge, near the base of the Falls, and the water is taken in at a point above the upper rapids, where a large deep forebay, with smooth water surface, and a series of ice screens have been constructed. The water is led from the forebay to the penstocks, a distance of about 1¼ miles, by three steel pipes, each of 18 feet diameter and an effective head of 175 feet of water on the turbines is secured. The turbines are arranged horizontally, and are coupled directly to the electric generators. A difficulty which confronted the Ontario Power Co. was the prevention of water hammer in the 4,000 foot length of pipes, through which water flows at 15 ft. per second. The trouble was overcome in a novel manner by constructing an enlargement in the end of the pipe close to the turbines opening into a weir, in which the water rises and passes away down a by-wash. In this way a free passage is given to the water when turned off at the wheel.

At present four generators are installed, each being driven by two turbines of the manufacture of Voit, of Heidenheim. The generators are each 10,000 H.P., and supply current at 12,000 volts, 3 phase, 25 cycles.

The general plan provides for 18 of these generators when completed.

The transforming and distributing station is erected in a handsome stone building 500 feet away and 280 feet higher up on the cliff. Communication between the two is established by an underground passage and elevator. The generators are all controlled from this station and the current is here stepped up to 60,000 volts for long distance transmission to Toronto. The management is thus concentrated in a single operating room. Hourly reports are sent from the engineer in charge of the power house by the telautograph.

The Ontario Power Co. is under contract to supply power to neighbouring municipalities for distribution for lighting and power at a price of $10.45 (£2. 2s.) per H.P. year, though for industrial purposes a higher rate ($18—$20) is charged. This company is now transmitting, by aluminium cable, 25,000 H.P. to Syracuse, where it is used in the electrification of the New York Central branch lines.

It is contemplated to develop 250,000 H.P. ultimately at this station, most of which will be available for use in the States.

There have at different times been various projects suggested for the transmission of the Niagara power to still greater distances, such as to Chicago and New York, but the demand for power in the immediate neighbourhood of Niagara Falls has increased more rapidly than the productive capacity. The result has been that the power produced has been absorbed locally, or within such moderate distances as Buffalo (18 miles), Toronto (80 miles) and Syracuse (160 miles). At present Buffalo takes about 24,000 H.P., and relies on this source for its street lighting and driving of trams. Toronto now takes about 10,000 H.P.

The chief industries at Niagara Falls which receive

power from the various power stations are enumerated below :—

Aluminium Co. of America	35,000	H.P.
Carborundum Co.	5,000	,,
Union Carbide Co.	15,000	,,
Castner Electrolytic Alkali Co. ...	7,000	,,
Oldbury Electro-chemical Co. ...	1,500	,,
Acheson Graphite Co.	2,000	,,
Norton Emery Wheel Co. Upwards of	650	,,
Niagara Electro-chemical Co. ...	2,000	,,

Niagara Falls is especially favoured by transportation services, being at the junction of Lakes Erie and Ontario, and at the convergence of several railways. By means of a canal to the Hudson there is also a waterway connection to New York.

Niagara Falls is a city of about 30,000 inhabitants, and although a great industrial centre, is quite free from smoke and other objectionable features of chemical works. Most of the factories, and especially the power houses, have considerable architectural pretence. The beauty of the Falls has apparently not been detracted from, and the town still holds its position as one of America's leading holiday resorts.

REFERENCES.—*Engineering*, Feb. 16th, 1906, vol. lxxxi, p. 218.
Proc. Instit. Mech. Engineers, 1906.

INDUSTRIES AT NIAGARA FALLS.

A short description of some of the more important electro-chemical works at Niagara Falls follows.

(1) *The Electrical Manufacture of Abrasives. Carborundum and Alundum.*

Introduction. Since information on some of the uses of abrasives is not easy to obtain, the following remarks

on the properties of these substances may not be without interest.

A comparison of the relative values of different abrasive materials is very difficult, and has apparently never been settled in any definite manner. So-called " hardness scales " are in very common use, in which the diamond is fixed at 10, and other materials given co-efficients according to the supposed relative hardness. The usual method of measuring the hardness of a substance is to find what well-known hard bodies, such as ruby, glass, etc., will be scratched by it. Another method is to place the material in a powdered and graded condition on a rotating disc and employ it for the grinding of a diamond, or of a piece of steel, measurement being made of the rate of abrasion. Results obtained in this way, however, are apt to mislead. In certain cases the cutting power of a substance depends on its brittleness as well as on its hardness, as, through fracture of brittle crystals, a sharp edge is continually being presented. This quality applies to abrasives used in the form of wheels or as powder. In other cases, however, such as in rock boring and drilling operations and for wire drawing, it is essential that the abrasive should combine great toughness with hardness. For this latter class of operations, the material which stands out pre-eminent, and which has never yet been superseded, is the diamond.

For the purpose of rock boring the most suitable form of diamond is the modification known as " carbon," a variety of carbonado, a substance which is dark-grey or black in colour, has no apparent crystalline form, and is much tougher than the crystal or gem stone. " Carbon " is found only in a small section of Mexico, and since its application to rock boring it has advanced very greatly in price, as may be seen from the following table :—*

* *Technical Literature*, 1907, vol. i, p. 245.

		£	s.	d.
In 1879 price per carat	... ...	1	0	0
,, 1889 ,, ,,	... ...	2	12	0
,, 1899 ,, ,,	... ...	7	0	0
,, 1907 ,, ,,	... ...	17	0	0

In diamond drill work, the "carbon" is set in circular pieces of soft steel or iron tubing about 4 inches in diameter, which are usually known as "bits."

These "bits" are attached to a vertical shaft, rapidly rotated, and pressed against the rock. A current of water flows down the tube at the same time. The hardest rock is quickly bored in this manner to a great depth, often amounting to several thousand feet. A set of carbons for each drill head or bit usually consists of eight stones, which, taking an average of 3½ carats, would, at the present price, amount in value to some £500 for the one "bit."

For the construction of diamond saws, as used for cutting building stones, a cheaper substitute known as "bort" is used. Bort is an imperfect crystal or gem diamond, and by very careful setting, is used with great success in stone cutting.

All endeavours to reproduce diamond on an industrial scale have so far proved fruitless, though H. Moissan, in 1892, demonstrated its formation and prepared small specimens in the electric furnace, and recently Sir W. Crookes has produced it by exploding cordite in a steel bomb, thus liberating carbon at an extremely high temperature and pressure.

A series of bodies have, however, been obtained of an allied nature to diamond, and which possess great hardness. These are compounds of carbon with similar elements, and can readily be obtained in the crystalline form by electric furnace processes. These substances, which are now manufactured quite cheaply, have very largely replaced the older abrasives, such as emery.

The two foremost, which have received a large industrial application, are "carborundum" or silicon carbide and "alundum," or fused alumina.

The former of these was discovered by E. G. Acheson in 1890, when experimenting on the formation of diamond, and was very quickly applied as a substitute for emery. The manufacture was started at Monongahela, Pa., and is now worked at Niagara Falls. The production at these works in 1891 and 1892 combined was half a ton; 595 tons in 1896, 2,380 tons in 1903, and is now (in 1907) about 4,000 tons.

Carborundum is manufactured in large furnaces about 16 feet long, 5 feet wide and 8 feet high, which are built up with brickwork and then filled in with the following charge:—

Sand	52·2
Coke	35·4
Sawdust	10·6
Salt	1·8
	100·0

A carbon core is placed in the centre to conduct the current across initially. The current is led in at the ends of the furnace through a number of carbon rods which are mounted in a terminal block, the copper leads being bolted to these blocks, which, in the later types of construction are water-jacketed.

In the main furnace room there are six furnaces in different stages of operation. The furnaces consume 1,000 H.P., and one in each series is run at a time. Some additional 2,000 H.P. furnaces are now in operation. On commencing to heat, an E.M.F. of 160 volts is necessary. By means of a regulating transformer, whilst keeping the power consumption constant, the E.M.F. is gradually lowered to 70—80 towards the end of the

operation as the furnace charge becomes more conducting. The heating of the material is continued for about forty-eight hours to cause the formation of carborundum; the furnaces are left to cool for the same period and then dismantled and the crystalline masses of carborundum removed and broken up. This crushing provides a large amount of powdered material.

Since the amount of powdered material thus obtained is in excess of the demands of the abrasive industry, attempts have been made to find other applications. At first, considerable use was made of carborundum as a deoxidizing agent in the steel industry, taking the place of ferro-silicon produced in the blast furnaces, but recently, however, ferro-silicon, prepared by the electric furnace, has replaced carborundum for this purpose.

Another application is as " fire sand " for the lining of fuel heated industrial furnaces, and in this line the material has proved most useful.

Carborundum bricks and other refractory articles have also been manufactured on a relatively small scale, and further developments may be looked for in this direction.

At the Niagara Falls works, the carborundum is largely made up into abrasive wheels, being, for this purpose, crushed, washed with acid to remove iron, and graded. The particles are then cemented together by some suitable binder, usually by binding with shellac or by mixing with clay which is then baked, after moulding into the desired shape. The wheels, when set, require trimming, for which purpose they are fitted with an axle and rotated against a cutting tool, which consists of three or four discs, the rotation of which is hindered by providing projecting ridges along the sides. The cost of power expended in the manufacture of carborundum has been calculated by Prof. J. W. Richards to amount to about ·62d. per pound of crystals obtained. The cost of materials and labour raise the cost to 1·3d. per pound, and the final cost, after crushing, washing,

and grading, may be 2d. to 2½d., whereas the material commands an average price of 4½d. per pound.

The current is supplied by the Niagara Power Co. at a voltage of 22,000, and is stepped down as required by the furnaces.

Alundum. Until the advent of carborundum, the abrasive available which was nearest to diamond in hardness was corundum. Corundum is an oxide of aluminium which occurs in nature in a pure state, and is mined extensively. It has generally a crystalline fracture, and is probably harder than alundum, though more brittle.

The artificial preparation of corundum was first accomplished by C. B. Jacobs, and the patents were bought by the Norton Emery Co., of Worcester, Mass., who applied its manufacture on a large scale, erecting works for this purpose at Niagara Falls, and putting the substance on the market under the name of alundum.* The process consists in fusing natural bauxite (alumina) in the electric furnace and allowing it to cool slowly, when it acquires the hardness of corundum and the toughness of emery, and is suitable for wheels, stones, paper and all the various uses of an abrasive.

The Norton Company at Niagara Falls, now manufacture 10 tons of alundum daily, the plant having recently been enlarged, and further extensions are being contemplated.

Each furnace yields a mass of the material of about 7,000 lbs. weight, which is broken up and then ground in a machine. This is then made up into wheels, after being, in some cases, first mixed with natural corundum, and is applied for a great variety of purposes. The wheels are said to be cheaper than those of carborundum for a given size, and are heavier. Alundum has found a successful application in the manufacture of dentists' drills which are formed by embedding the alundum in a

* A. C. Higgins. U.S. Patent, No. 775,654, 1904.

layer of copper deposited electrolytically around the grains. It is also used for grinding glass for optical purposes, and some tests are said to have also been successfully carried out on its use in rock boring.

With regard to the comparative merits of carborundum and alundum, the former is said to show marked superiority when used on cast-iron, brass, and marble, and for roughing out unevennesses in coarse work. This is on account of the ease with which the crystals force their way into the work, and the great length of time they will last before dulling. Hence the efficiency of carborundum is mainly due to its penetration, and is best adapted for comparatively soft materials, in which its quality of sharpness is of more value than its hardness.

For the abrasion of materials such as hardened steel, however, and for finishing cuts and polishing purposes, alundum is better adapted, as though not so hard and sharp, yet it is less brittle, and enables the use of a greater pressure.

*Artificial Graphite.** Artificial graphite has been known since the work of Despretz in 1849, and was first produced commercially by the Girard and Street process which consisted in passing amorphous carbon through the electric arc.† See page 103.

The industrial manufacture of this substance has, however, been developed on a much larger scale in America by Mr. E. G. Acheson. This industry followed from an observation of Mr. Acheson that in the centre of the carborundum furnace, graphite resulted from the overheating of carborundum. Further experiments showed that all carbides are decomposed by heat, leaving behind graphite. It was next discovered that the

* *Electrochem. Ind.*, 1905, vol. iii, 253.

† Hutton and Petavel. "High Temperature Electro-chemistry." *Proceedings of the Institution of Electrical Engineers*, November 1902.

presence of silica will bring about the conversion of a large amount of carbon into graphite at a high temperature. This is caused by the successive formation and decomposition of silicon carbide, the action of the silicon being a catalytic one. This process was put on an industrial basis, and a company organised, known as the Acheson Graphite Co., in 1899. The operations have resolved themselves into two lines of manufacture—(1) the graphitisation of moulded carbons; (2) the graphitisation of anthracite coal *en masse*. The product in both cases is graphite of a high degree of purity which, in many forms, has now found an extensive application. Articles which are moulded for graphitisation include electrodes in all sizes, lamp carbons, and carbon bars and plates. These are prepared by taking some form of amorphous carbon, such as coke, in a fine granular condition, mixing with a small quantity of tar (probably about ½ per cent.), and then moulding into the required form by squirting the carbon, through a die of suitable shape, by means of a hydraulic press. The articles are then stacked transversely in a furnace of similar design to that used for carborundum, each separate piece being packed around with granular coke and covered with carborundum. The current terminals are about 30 feet apart, and consist of carbon rods, to the number of nine, fitted with brass caps, which, unlike those in the carborundum furnaces, are not water-cooled. The articles to be graphitised are arranged in the centre of the furnace, which is built up by temporarily inserting thin sheet-iron plates to act as a partition for the central zone. This inner space is then filled in with the carbon articles and separating layers of granular coke, and the outside is filled in, and the top covered with "white crust" (siloxicon) to serve as insulating material. Small articles to be graphitised, such as thin carbon rods, are placed inside larger tubes to protect from

fracture. Heat is generated by the passage of the current through the granular coke, which maintains a comparatively high resistance throughout. The furnace starts with 3,000 amps at 220 volts, the current gradually increasing to 9,000 amps. at 80 volts after a twenty hours' run.

The building contains two rows of five furnaces, and, as in the carborundum manufacture, one furnace is run at a time, while the others are in various stages of dismantling and preparation.

In the process of manufacturing graphite in bulk, anthracite coal is taken as the starting-point, being specially adapted on account of the uniformly distributed ash which it contains. Purer forms of carbon, such as petroleum coke, which only contains 0·3 per cent. ash, graphitise much less readily. The furnaces for this operation are 30 feet long and of 2 feet square cross section, and are made of bricks and lined with carborundum to a thickness of 6 inches. The anthracite coal to the amount of about 6 tons is then introduced in large lumps, and a core of granular carbon, partly graphitised, about 6 inches wide, is laid from one end to the other in order to start the current. Prof. J. W. Richards estimates that about 82·5 per cent. of the energy is consumed in raising the charge to the graphitising temperature and 17·5 per cent. radiated during the run, and that the heat evolved in conversion of amorphous carbon into graphite amounts to fully 10 per cent. of the heat supplied by the current, which, on the other hand, is just about balanced by the heat absorbed in volatilising the 5—10 per cent. of impurities from the coal.

The introduction of artificial graphite has proved to be of the utmost value to electro-chemical industries, and particularly so in its application to electrolytic alkali processes for the construction of electrodes, on account of being a good conductor and very resistant chemically.

Graphite is very soft and tough, enabling it to be turned and machined with the greatest ease, and it is thus particularly suited for the construction of apparatus used in electric furnace work.

The growth of the manufacture of artificial graphite is shown by the following figures:—*

1897	81 tons.
1900	440 ,,
1904	1,333 ,,
1905	2,250 ,,

According to the U.S. Geological Survey, the value of Acheson graphite made in 1904 was $217,790. Since 1904 the plant has been increased from 1,000 to 2,000 H.P.

A soft unctuous form of graphite is prepared which has valuable properties as a lubricant as it does not coalesce under pressure. This is formed in special furnaces which are provided with a starting core of graphite rods, the charge consisting of carbon together with ash or silicon in amounts in excess of that employed in the manufacture of ordinary graphite.

A further variety of graphite has now been prepared in a colloidal condition by treating the above variety with a solution of gallotannic acid. This so-called "deflocculated" graphite remains permanently suspended in water or oil, giving a material which has proved to possess valuable properties as a lubricant. (*Electrochem. and Metall. Ind.* (1907), v., page 452.)

Siloxicon. At the Acheson graphite works, furnaces are erected for the manufacture of siloxicon. This is a refractory material containing silicon, carbon, and oxygen, and is prepared by heating in an electric furnace a mixture of carbon and silica, the latter being in excess over the amount needed for silicon carbide.

* *Electrochem. and Metallur. Ind.*, 1905, vol. iii, p. 253

The furnaces are arranged for the current to pass along carbon rods arranged transversely to the furnace and connected at each side to a group of graphite blocks. The current in this manner passes from side to side twenty times on its way through the furnace, and the contained charge is raised to the necessary degree of temperature.

Siloxicon is a greyish-green powder which can be formed into a coherent mass by grinding, moistening with water, moulding and baking. It is very refractory, not attacked by slags, is insoluble in iron, and is indifferent to acids and hot alkaline solutions.

*Electrolytic Alkali and Chlorine works, Townsend Cell.**

By far the largest enterprise engaged in this manufacture at Niagara Falls is the Castner-Kellner process, which operates on the well known mercury cathode principle. A new system possessing many points of interest, has however lately been devised. This is the Townsend process which works on the diaphragm system. Works have been erected by the Development and Funding Co. for its exploitation. Diaphragm cells hitherto in use possessed the disadvantage of yielding only dilute alkali on account of the difficulties in preventing the caustic soda from diffusing back into the anolyte, and thus leading to waste and exerting an oxidising action on the anode. This diffusion, moreover, increased with the concentration of the solution.

The method of obviating this difficulty by transforming the alkali into carbonate appears to be a backward step from the commercial standpoint, as it transforms high priced caustic soda into low priced carbonate.

The Townsend process is described as "counteracting diffusion and recombination of cathions and anions by automatically subtracting every drop of cathode liquor,

* *Electrochem. and Metall. Ind.*, 1907, vol. v, p. 209.

as soon as it appears, and surrounding it with a chemically inactive and physically immiscible liquid." Kerosene is the liquid used in practice.

This process, which was designed by Mr. C. P. Townsend in collaboration with Mr. Elmer A. Sperry, is carried out in a cell of similar construction to that of Hargreaves and Bird. The cells measure $8' \times 3' \times 12''$. The anode space is enclosed between two vertical diaphragms and contains saturated brine. Graphite anodes are fitted through the lid. The diphragms are in close contact with perforated iron cathode plates, and a little distance from this are the iron sides of the cathode compartment which contains kerosene oil.

The higher specific gravity of the brine solution and the fact that this is kept at a higher level than the kerosine, creates a hydrostatic pressure, and causes the brine to press through the diaphragm and flow into the kerosene. Under the action of the current this percolating liquid becomes changed into alkali, the concentration of which will depend on the current density. Each drop of liquid as it passes through the diaphragm acquires a globular shape when coming into contact with the kerosene oil, due to surface tension; the caustic alkali thus becomes separated and sinks to the bottom of the oil and accumulates in a pocket.

A trapped tube drains this liquid from underneath the kerosene. In this manner the rich cathode liquor flows out continuously on both sides of the cell, and is led by pipe lines into the general storage tank, from which it passes to the evaporating pans, where the remaining salt is separated by concentration.

The cost due to the loss of kerosene is said not to exceed $2 a day, in the plant in question.

The spent anode liquor consisting of weak salt solution is regenerated by treating with a further quantity of salt. An E.M.F. of 5 volts is used, and an ampère

efficiency of 95—97% and an energy efficiency of 60% obtained.

The Townsend cell has been in continuous operation at Niagara Falls since the beginning of 1906, and since that time has been producing daily about 5 tons of caustic soda, and 11 tons of bleaching powder.

Production of Aluminium at Niagara Falls.

The Aluminium Company of America.

In 1885, the Cowles brothers of Cleveland, Ohio, invented a process for obtaining alloys of aluminium by direct reduction of alumina with carbon in presence of metals such as iron and copper. The Cowles Electric Smelting and Aluminium Company was formed to work this process and a plant was erected at Lockport, N.Y., where a water power of 1,200 H.P. was secured. Following the success of this American plant, the Cowles Syndicate Company was formed in England and a works erected at Milton, Staffordshire, which had a capacity of about 300 lbs. of aluminium alloy daily. The important processes which have now caused aluminium to rank with the ordinary commercial metals, and which have superseded the older methods are those designed and patented by Hall in the States, and independently by Héroult in France, between the years 1886 and 1889. The principle of both of these methods consists in the electrolytic decomposition of alumina dissolved in a bath of fused cryolite, the current reducing the alumina and not affecting the solvent.

In America, this process was operated by the Pittsburg Reduction Company from 1889 to 1891, at Pittsburg, Pa. During 1889, the company produced about 75 lbs. of aluminium a day which they sold at $4.50 per pound. In 1890, their capacity was increased to 400 lbs. and the selling price reduced to $2 per pound.

The Aluminium Company of America, which is the

title under which the Pittsburg Reduction Company is now known, holds, at the present time, practically a monopoly of the manufacture of aluminium in the United States and Canada. Works are in operation at Niagara Falls, Massena, N.Y., and Shawinigan Falls, whilst auxiliary factories of the company undertake the purification of the alumina, the production of the carbon electrodes required in the process, and the rolling and working of the metal into finished products ready for the market.

Of the two large plants at Niagara Falls, one is situated half a mile above the Power House of the Niagara Power Co. and was the first to utilise this power; 4,000 H.P. is taken from here, the alternating current is received at 2,250 volts and converted, by means of transformers and rotary converters, to direct current at 160 volts. The lower works is situated on the edge of the gorge below the falls, and, up to 1906, took 6,500 H.P. from the Hydraulic Power and Manufacturing Co. An additional 27,000 H.P. has now been laid down at the lower works.

The current is conducted by aluminium bars through a line of cells, each cell taking about 5 volts and absorbing 65 horse power. About one half of the energy is expended in the chemical work of decomposing the alumina and the remainder is converted into heat which serves to keep the bath at the proper temperature, about 850° to 900° C. The bath consists of cryolite to which is added aluminium fluoride and in which alumina is dissolved.

The aluminium process is typical of the simplification which is brought about in metallurgical operations by electro-chemical methods. The heat losses in the molten cryolite bath are minimised by putting a layer of pulverised carbon on top of the bath; the alumina which is subsequently to be used

in the cell is supported on this supernatant layer and is dried by the waste heat.

During operation the bath becomes impoverished in alumina, the extent of which is indicated by placing a 20 volt lamp in shunt between anode and cathode. The deficiency in alumina causes an increase in resistance, and the resulting increased voltage across the terminals of the vat lights up the lamp. This is a sign to the workman to add fresh alumina, which is effected by simply stirring the surface of the bath when the alumina sinks through the supporting carbon layer and is rapidly taken up by the molten cryolite. The whole process is thus quite continuous and requires relatively little attention.

On both commercial and technical grounds the production of pure alumina forms a very important part of this process of manufacturing aluminium, and, at the present time, the method of Bayer, in some more or less modified form is almost exclusively used, both in Europe and America.

A process of purifying alumina has recently been invented by Hall, and consists in mixing the bauxite with sufficient carbon to reduce the impurities, and then smelting the mixture in an electric furnace. Impurities such as oxides of iron, silicon and titanium are reduced to a metallic alloy which collects on the bottom, and leaves the alumina in a pure state. This method, however, is said to have the great drawback of leaving the alumina in a form which will not dissolve in the cryolite bath, on account of the high temperature of the treatment.

The lower Niagara plant of the Aluminium Company of America is situated immediately above the power house of the Hydraulic Power and Manufacturing Co. The continuous current required is generated in the power house by dynamos of 750 horse power each,

coupled direct to turbines with horizontal shafts. Each dynamo gives a direct current of 2,000 amps. at a potential of 280 volts. Nine such machines furnish the 6,500 horse power necessary to run three lines of cells.

This lower plant has now undergone a large extension, an additional 27,000 H.P. being used as mentioned above.

The company owns large deposits of bauxite or native alumina in Georgia and Alabama.

Aluminium has attained the greatest importance in the electrical industry, being used as a substitute for copper conductors for transmission lines. The three largest electrical power transmission lines in the United States are of aluminium. One in California is 144 miles long. One from Niagara Falls to Cleveland 200 miles, and to Syracuse 160 miles. This last lead is in three cables of 19 strands each, and a voltage of 60,000 is used. The aluminium line from Niagara to Buffalo was said to cost 12 per cent. less than the copper one.

The steel industry has become an important consumer of aluminum, small quantities of this metal, viz.,2·8 ounces per ton of steel are usually added during the furnace treatment.

Aluminium has found a large application in the manufacture of "thermit" which is now used extensively in welding.

During 1906, the profits earned by the Aluminum Company of America, amounted to £708,000 as compared with £370,000 for the previous year.* This corresponds to a gross profit of 7·8d. per lb. of aluminium for 1905 and 11·4d. per lb. for 1906. The consumption of aluminium in the States in 1905 amounted to 5,670 tons, of the value of £649,000, and in 1906 to 7,450 tons.

* *Electrician, March* 27th, 1908, p. 907.

The world's production of aluminium in 1907 was as follows :—

	Metric tons.	Value.
United States and Canada	8,000	£880,000
Germany, Austria, and Switzerland	3,500	£385,000
France	6,000	£660,000
United Kingdom	1,800	£198,000
Italy	300	£33,000
Total	19,600	£2,156,000

REFERENCES.—*Electrochem. Ind.*, vol. i, p. 49. *Journal d'Electrolyse*, May 1st, 1908, p. 1.

The Union Carbide Company.

Calcium carbide was first made industrially by Willson at the Willson Aluminium Works at Spray, N.C., in 1891.

Since then its manufacture has become one of the largest of the electro-chemical industries.

The Union Carbide Company controls almost all the production of carbide in America. The works are situated about one and a half miles from the power house above the falls, and are supplied through a conduit with some 15,000 H.P. of alternating current at 2,250 volts which is subsequently transformed to suit the requirements of the manufacture.

The furnaces employed are of the Horry type and consist of iron drum shaped casings with a recessed rim on top of which are bolted segmental wings 24 inches deep. In the space thus created, the two carbons dip on top of the wheel and melt the charge of lime and carbon there fed to them. The whole furnace rotates very slowly, about once in 24 hours; the fluid carbide is thus removed from the hot zone, solidifies, and by removing

the bolted plates, is taken from the other end of furnace comparatively cold.

Each furnace is 8 feet in diameter and 3 feet wide and takes 3,500 amps. at 110 volts, or 500 horse power.

The carbons are 6 inches in diameter and are kept about 9 inches apart.

The Union Carbide Company also possesses a works at Sault Ste Marie (p. 49).

A new factory, where 10,000 H.P. will be utilised is being erected at Duluth.

The output of calcium carbide in the different countries is estimated as follows:—

	1905. Tons.	1906. Tons.	1907. Tons.
United States...	—	—	25,000
Italy	—	28,357	—
Germany	16,547	22,340	24,916
France	—	24,000	—
Great Britain ...	—	less than 3,000.	

CHAPTER III.

THE COPPER REFINERIES OF NEW JERSEY.

It is in copper refining that electro-chemical methods have attained the greatest industrial importance. This process has undergone the most important development in the United States as is indicated by the fact that more than 85 % of the world's output of electrolytically refined copper is produced in that country. There are about 8 refineries in the States with a total output of about 350,000 tons per year.

The leading ones, with their maximum output, are tabulated below :—

	Tons Per day.	Per year.
Amer. Smelting and Refining Co. at Maurer	160	60,000
Raritan Copper Works.........	360	129,600
De Lamar ,, ,, ...	160	60,000
Balbach ,, ,, ...	50	18,000
Nichols Refinery, Brooklyn...	250	91,200
Total.........		358,800 tons

The first commercial refinery in America was built early in the eighties by Messrs. Balbach and Sons at Newark in New Jersey. This district is now the seat of practically all the copper refining in America.

Very important plants were formerly in operation at Anaconda, and at Great Falls in Montana. These are now said to be closed down however, on account of the high price of labour and materials in that district, it

being found more economical to transport the crude metal and refine in New Jersey.

The great value of the electrolytic refining of copper lies in the complete recovery of the gold and silver, and the production of a very pure form of copper, which is specially suitable for electrical purposes on account of its high conductivity.

The short description of the Maurer works which follows is given as a typical example of the American copper refineries.

This plant was erected in 1896 at Maurer, near Perth Amboy, by the Guggenheim firm and now forms one of the plants of the American Smelting and Refining Company, which also possesses refineries at Omaha (Nebraska) and in South Chicago. The works is especially favoured by transport facilities by land and water. The crude metal or blister copper is imported chiefly from Mexico, in boats owned by the company, and also from their own smelting works in Colorado and Utah.

The smelting of lead and copper ores is also carried out at this refinery to a small extent, the lead obtained being used in the slime's treatment for cupellation. The daily output of refined copper in October, 1906, amounted to about 100 tons, with a recovery of 100,000 oz. of silver and 70 oz. of gold.

The crude metal contains about 96% copper, and is very rich in gold and silver. This is melted down in a reverberatory furnace thereby being partially refined, and is then cast into anodes in a form suitable for suspending in the electrolytic tanks. The casting is done by means of a Walker machine in which the anode moulds are fixed in a circle around a rotating wheel near the furnace. A long spout projects conveying the metal and the moulds are brought under this and filled in turn by rotating the wheel. On reaching the opposite end of the wheel the cast metal is sprayed with water and removed.

The cathode starting sheets are formed by electro-deposition, copper for this purpose being deposited on a plate with oxidised surface, and then stripped off.

The vats, to the number of 800, are arranged on a sloping floor to permit of circulation of the electrolyte, which is pumped from the lower cells into a raised tank, where it is heated with steam, and allowed to flow into the top vats.

Each tank, which is 10 feet long, 3 feet deep and 2 feet 6 inches wide, contains 22 anodes and 23 cathodes. The anodes are 3 feet high, 2 feet wide, 1·25 inches thick and 275 lbs. in weight. The composition of the electrolyte is 16% copper sulphate and 6% sulphuric acid. A current density of about 10 amps. per sq. foot is used and a period of 24 days needed to transfer the copper from the anode to the cathode plate. The E.M.F. necessary for each cell averages between ·2 and ·4 volt.

The amount of current employed in the electrolysis is 3,000 amps. at 120 volts. The electrolyte is regenerated from time to time, on account of the accumulation of an excess of copper through the formation of cuprous sulphate. The excess of copper is removed by electrolysis in auxiliary vats with lead electrodes.

Eventually the electrolyte becomes too contaminated with impurities for further use, when the copper sulphate is separated by crystallisation and finally by the addition of scrap iron, and the residue thrown away.

The anode slime, which contains all the gold and silver and most of the other impurities of the copper, accumulates at the bottom of the tanks, whence it is carefully removed and dried; the average composition of the slime is 15·30% metallic copper, 45·50% silver and 5·1% gold.

The cathodes consist of pure copper which finds a ready application for electrical purposes on account of its high conductivity. The silver slimes are mixed with a certain amount of lead and cupelled in a furnace, thus

causing volatilisation of arsenic and other impurities, and yielding doré bars. These are subsequently parted electrolytically by the Moebius process. This process, in very brief outline, is as follows:—

An electrolyte of nitric acid, copper nitrate, and silver nitrate is placed in vats about 2 feet 6 inches deep. The anodes of doré metal are about 5 inches wide by 12 inches deep, a number of these are placed side by side in canvas walled cells, into which the gold drops as the electrolysis proceeds. The cathodes, which consist of thin silver sheets, are laid about 3 inches from the walls of the canvas bags. Agitation of the electrolyte is effected by means of wooden sticks, which are connected to a spindle at their upper ends, and suspended in the electrolyte on either side of the cathodes. A swinging motion, backwards and forwards, is imparted to these. Growths of spongy silver are thus removed and caused to fall into a wooden frame placed underneath in the vats. At the end of the electrolysis, the electrodes and frame are raised together out of the bath and the deposited silver, in a snow like form, is brushed from the cathodes and shovelled away, to be afterwards melted down. The gold, in the form of a black powder, all remains behind in the canvas sacks and receives a final chemical treatment and is then melted into bars.

The processes at the above refineries all work on the multiple system, the anodes and cathodes being placed alternately and the current passing from all the anodes in parallel to all the cathodes joined in the same way.

In the series arrangement, which is in use at an important refinery at Baltimore, the anode and cathode are placed at the extreme ends of the vat and a number of intermediate, or bipolar, electrodes are arranged in between at regular intervals. The current is passed through these in series, when copper is dissolved from one side of each electrode and deposited on the other

side. By previously oxidising the surface, or coating with carbon or grease, the deposited copper can readily be stripped away from the remaining metal sheet.

With regard to the relative merits of the multiple and series systems,* twice the amount of copper as anodes is needed in the multiple as compared with the series system, hence a greater value of metal is locked up in the process of treatment. By taking thinner anodes, the percentage waste is much greater and plates must be renewed oftener at an increased labour cost. On the other hand the volume of the electrolyte in the series arrangement need only be one fourth that in the multiple system, and the electrolysis is carried out at a higher temperature (48° C.) thus decreasing resistances and in consequence the size of plant. By making the electrodes very smooth and homogeneous by rolling, the distance apart in the vats has been decreased to as little as ·5 to ·8 inches.

The cost of preparation of anodes for series work overbalances the gain attained by economy of power and reduced value locked up in plants.

In the older practice, and carrying but 2 to 4 amps. per square foot, the refineries needed an outlay in stock of 75 to 100 times their daily production, lately with 15 to 17 amps. only one-fifth of this amount has been needed.

The current density depends on the purity of the anode copper, so that while 8 to 10 amps. would be advisable for impure copper, for specially fine anodes, as high as 40 amps. has been employed.

Nickel Refining.

A process of nickel refining is at the present time operated on a small scale in New Jersey at the Orford Copper Co. by an electrolytic process of Mr. W. Thum.

* *Mineral Industry*, vol. xv, p. 293.

Nickel sulphide, which is separated from the copper-nickel matte resulting from the smelting of the Sudbury ores, is said* to be treated by an electrolytic process in which the nickel sulphide is used as anode material in a vat containing nickel chloride as electrolyte. In this way, the nickel is dissolved and deposited in a pure state on the cathode, while sulphur is liberated in a free state at the surface of the anode.

* Kershaw. *Electro-Metallurgy* (1908), p. 236. See also Pring, U.S. Patent 874,864, December, 1907.

CHAPTER IV.

CANADIAN WATER POWERS AND ELECTRO-CHEMICAL CENTRES.

CANADA is especially favoured by an abundance of water powers. Except in the prairie region, the rivers are characterised in not being naturally navigable to any considerable extent from their mouths, on account of their frequent interruption by falls and rapids.

Development of water power has now been undertaken at numerous places chiefly in the east and extending as far west as Winnipeg. The Government takes a very active interest in the development of these water powers, and in June, 1906, offered for sale at public auction, 16 sites representing a total of 730,000 H.P.

Westward of Winnipeg, the long stretch of prairie, necessarily possesses no waterfalls, but, beyond this, we reach the Rocky Mountain district in British Columbia which contains the greatest of all Canadian water powers. The falls in this district are chiefly characterised by possessing great head. The amount of power to be obtained from the streams of the Rocky Mountains and from the wide rivers with their large volume of swiftly flowing water is of enormous magnitude. The harnessing of these water powers should prove comparatively easy, though at present very little has been accomplished on account of the very scanty settlement of this part of the country. Developments are taking place rapidly, however, and two or three important power stations are now in successful operation in British Columbia.

*Region of the Lower St. Lawrence.**

Considering first the most easterly of the Canadian water powers and then proceeding westwards, we have, first, the St. Lawrence River with its numerous tributaries which contain many falls and rapids. Beginning at the extreme east, the first tributary of any importance is the Matapedia River on the south bank, near the Gaspé peninsula. The Matapedia Valley is a valuable farming and lumber district, and the river affords numerous water powers, some being equivalent to 4,000 H.P. These are applied to a small extent to the working of saw mills.

Region of the Eastern Townships.

This district, which is an important grazing country, lies at the south of Quebec, and possesses rivers which contain many water powers. The principal rivers here are the Chaudière, Saint Frances, Nicoles and Bécancour. Many of these water powers are already utilised for saw mills and various manufactories.

The St. Maurice Region.

This extensive territory, called the Valley of the St. Maurice, is situated on the north of the river St. Lawrence, behind the town of Three Rivers.

The St. Maurice, which drains the greater part of this region, is a river, the waters of which are rapid and sometimes deep, and which runs from north to south, falling into the St. Lawrence.

For a distance of 200 miles from its mouth, the river has an average width of a quarter of a mile. The region through which it runs is generally very mountainous, and the river is impeded by a great number of rapids and falls, the most important being those of Shawinigan, La Tuque and Grand'Mère.

* A. Turgeon Report of the Minister of Lands and Forests in the Province of Quebec (1906).

The St. Maurice River contains a large number of lakes scattered over its watershed which act as reservoirs, and thus equalise the flow of the river.

Shawinigan Falls.

This place is situated about half-way between Quebec and Montreal, and at a distance of about 85 miles from the latter. An important power development has here been carried out by the Shawinigan Falls Power Co. Very wide concessions were made by the Government to this company in the matter of expropriating land required for the purpose of transmission lines. Shawinigan Falls is situated on the Great Northern Railway between Quebec and Montreal.

The town of Shawinigan Falls has been laid down with a view to the erection of a model manufacturing town. A portion has been reserved for mill sites, and the rest laid out in lots for residential purposes. The population of the town, which dates from 1900, now amounts to about 4,000.

A total development of 25,000 H.P. from the Falls has now been achieved, most of which is transmitted to Montreal by an 85 mile line of aluminium. The current is stepped up to a voltage of 50,000, 3 phase. The transformers are oil-cooled and placed in a separate building. A special device is fitted to each transformer to afford protection in case of fire. The oil in the tank for this purpose can be displaced by water and forced into the sewer.

The principal industries around the Falls are the Northern Aluminium Company—a branch of the Aluminium Company of America, where aluminium metal is obtained*—the Carbide Company, manufacturing calcium carbide, and the Belgo-Canadian Pulp Company, which operates large paper mills and takes 8,000 H.P. A transmission line has now been built

* The output of this metal in 1905 was 1,035 tons, in 1906, 2,700 tons.

across the St. Lawrence River conveying power from the Falls to the asbestos mines of Black Lake and Danville.

The town of Grand'Mère arose in 1899 to utilise the La Tuque water power, and the Falls of the Grandes Piles. The latter has an estimated minimum power of 23,000 H.P. Grand'Mère has now a population of 2,500 inhabitants.

There are numerous other water powers in this district which have not yet been developed, and which offer a valuable field to the opening up of new manufacturing industries.

The Lake St. John and Saguenay Region.

Lake St. John lies to the north of Quebec, and the surrounding Saguenay region, embracing an area of 30,000 square miles, contains an abundance of water power which could easily be made available for industrial purposes.

This district is renowned for its valuable hunting grounds and fisheries, for its forests and the fertility of its soil. Among the tributary rivers of Lake St. John are:—

(1) The Metabetchouan, which possesses a waterfall of over 200 feet in height, and three rapids.

(2) The Quiatchouan, which forms at two miles from its mouth, a fall of 236 feet in height.

(3) The Grand Peribonka, which, at a distance of some five miles from its mouth, has seven waterfalls, formed one above the other, and which could develop a motive power of 300,000 H.P.

(4) The Little Peribonka, which, at the town of Dalmas, forms the "Chutes Blanches," where hydraulic power is used by the Peribonka Pulp Factory.

(5) Mistassini, which has falls and cascades at the 24th, 35th, 40th and 144th mile from its mouth. One of these falls is 80 feet high.

(6) Mistassibi, which has seven falls in the 34 miles of

its course, the most important being the Chutes des Pères, which are 45 feet high.

The Rivière aux Rats is a tributary of the Mistassini, and, in the first seven miles above its confluence with the latter river, forms falls of 30, 40 and 60 feet in height capable of furnishing a force of 125,000 to 150,000 H.P.

The River Chamouchouan, at a short distance above the village of St. Félicien, and about 15 miles from Lake St. John, contains cascades and falls of great size. It is calculated that in the 50 miles of its course, the hydraulic force of this river would easily produce 300,000 H.P.

Very large water powers are also met with in the counties of Chicoutini and Saguenay, notably those of the River Chicoutini, au Sable, Shipshaw, Saguenay, Portneuf, Ste Marguerite, Grande Trinité, Petite Trinité, Esconmains, Sault-au-Mouton, Bethsiamis, aux Ontardes, Manikuajon, Pentecote, aux Rochers, Marguerite, Moisie, Natashquan, etc., etc. Some of these are already employed by large manufacturing establishments, notably that of the Chicoutini River, where the Chicoutini Pulp Company has erected very large works. The hydraulic powers of the Rivers Marguerite and Trinity are worked by two companies—American and English.

This Saguenay district now contains a number of growing settlements, and is well served by transportation facilities. Numerous steamers ply regularly on Lake St. John and the Saguenay River in summer.

The Quebec and Lake St. John Railway runs through the whole region between Quebec and Lake St. John, and is 192 miles long. A direct line also connects this interesting district with Ottawa.

Great Falls, New Brunswick.

An important electro-chemical works is in operation at Great Falls, New Brunswick, for the reduction of manganese ores, which occur in the neighbourhood.

These are here converted into ferro-manganese alloys of high quality.

Lachine Rapids, Montreal.

At these rapids the St. Lawrence River itself undergoes a drop of 16 feet. Some 8,000 H.P. is at present generated from this source, and is used in Montreal.

The Ottawa Region.

This region comprises an area of forest land of over 40,000 square miles. The Ottawa valley is bounded on the south by the St. Lawrence, on the west by the city of Ottawa and Lake Temiscaminque, on the north by the height of land dividing the basin of the St. Lawrence from that of Hudson's Bay, and on the east by the tributaries of the right bank of the St. Maurice.

The chief industry of this country is that of lumbering, though mining, and especially the quarrying of phosphates, which are found in large deposits in many townships of the Ottawa valley are contributing greatly to the development of colonization here.

The Ottawa River contains a large number of tributaries which furnish good water powers. On the main river the chief are:—

Chaudière Falls at Ottawa. Power is here developed on a small scale for the electrical supply of the city and for the operation of lumber mills in the district. The chief power company, that at Hull, Ottawa, sells power at $15 per H.P. year.

Chats Falls. "Les Chutes des Chats" on the Ottawa River are situated four miles from the Quyon station on the Pontiac Railway, and 33 miles from Ottawa. These falls promise to give rise to an important industrial centre in the future. A careful examination and measurements of the falls have been made with a view of applying them for the generation of power, and, as mentioned below in the section on iron smelting, a scheme has been put forward to establish here an iron

smelting centre. The Chats Falls have a difference in level of 36 feet between head and foot and the flow during mean low water level has been estimated at 17,200 cubic feet per second.

This corresponds to a theoretical power of 70,000 H.P., and, it is considered, that the total maximum power that can be practically derived amounts to 50,000 H.P. Development of power at this place promises to be free from difficulty.

About one-third of the whole discharge of the Ottawa at the " Chats " passes on the Quebec side. The water privileges for this power, amounting to about 15,000 H.P., have been valued at $18,000, and it is thought advisable to sell this power in three sections, reserving one for the operation of a railway to be constructed in the district.

The value of the Chats Falls is at present diminished through the existence of other water powers situated nearer Ottawa. In addition to the Chaudières Falls at Ottawa itself, there are the Deschênes Rapids within five miles from the city. These form a very fine water power from which the Deschênes Milling Co. and the Hull and Aylmer Electric Railway on the Quebec side derive their power.

The " Metropolitan Electrical Company of Ottawa " is about to erect a 5,000 H.P. plant at Britannia, on the Ontario side of these falls.

This company possesses 160 acres of land along the river, which was purchased together with the water rights, affording a total of 20,000 H.P., for the sum of $20,000.

The falls of the Grand Calumet form another important power on the Ottawa River, though they present some difficulty in developing. The power of these falls is estimated at 6,000 H.P.

Among other big water powers of the River Ottawa are " Les Chutes et Cascades du Chenal du Rocher

Fendu," south of the Grand Calumet Island and north of the Allumette Island.

At the western extremity of this part of the Ottawa River called the Rivière Creuse, we meet the falls and rapids of the Joachims, the rapids "du Rocher Capitaine," of the "Deux Rivières," "du Levier" and Mattawa.

The water power from the Joachims in front of Aberdeen, in the county of Pontiac, is capable of furnishing a minimum of 13,000 H.P. The cascades on the River Gatineau, a tributary of the Ottawa, is calculated as equal to 40,000 H.P., and the rapids of St. Joseph and Des Eaux, on the same river at 7,700 H.P.

The rapids of Mattawa and Johnson together will give 7,500 H.P.

On the River Ottawa the water power of the Long Sault Rapids is estimated at 20,681 H.P.

The Region of the Temiscamingue.

This embraces an immense territory comprising the valleys of the Lake Temiscamingue and the River des Quinze, which is itself a continuation of the River Ottawa.

This district is of interest from an agricultural standpoint, and on account of its immense forests and abundance of game; it has also attained considerable importance as a mining centre on account of its mineral resources.

The numerous rivers and streams in this district form many sources of power, some of which are of great value. The River des Quinze alone possesses 15 falls, and the River Kepewa and La Lontre several important ones.

The following is a description of the water powers offered for sale at public auction in June, 1906. The Government concession takes the form of a lease for 99 years, and is given on condition that the lessee expends a definite sum within a period of five years, the

amount being in each case determined by the size of the water power. In default of this expenditure the lease is cancelled.

Name of Power and Situation	Height of fall feet	Estimated Total Power available at low water H.P.
Kai-Kai-Ke Rapid on River des Quinze near North Temiscamingue	46	15,640
Island Rapid, River des Quinze, near North Temiscamingue ...	95	32,000
Discharge of Lake Tremblant near Trembling Mountain station ...	36	360
First Falls on River Manicouagon, Saguenay County, on North Shore of St. Lawrence ...	110	331,456
Falls of the River aux Outardes, Saguenay County, on North Shore of St. Lawrence ...	200	180,992
La Gabelle Rapid on St. Maurice River, near Three Rivers, on the line of the St. Maurice Valley Railway	20	8,000
Coteau Rapids on the St. Lawrence at Coteau du Lac, County of Soulanges. Close to the Grand Trunk and the Canada Atlantic railways, and also to the Soulanges Canal	12—15	10,000—15,000
Iroquois Falls on the Vermillion River, 21 miles above La Tuque	35	1,200
River Manouan Falls	30	1,000
Grand Sault on River Rimouski...	50	500
Rapide Malin, River Bonaventure	6	700
Chandiere Falls on River Chamouchouan, Lake St. John County	60	12,000
Chute des Pères, River Mistassibe at Pelletier, Lake St. John County...	42	11,848
Falls of Sault au Cochon, Saguenay County, one mile from St. Lawrence River	—	2,000
Great Bear Falls on River Chamouchouan, 18 miles from Lake St. John	80	100,000

In most of the above cases the lease includes possession of the banks of the river for a considerable distance up stream, so that the available head of the falls, and consequently the power can, in a good many cases be artificially increased :—

List of Water Power sold in the Province of Quebec from 30th June, 1905, to 1st July, 1906.

Names and Places	Approx. H.P. available	To whom sold or leased	Price and condition of sale or lease
Rapide des Hêtres, St. Maurice River, Champlain County.	1,400	The Shawinigan Lakes Power and Electric Co.	$1,500
St. Anne River, County of Porneuf.	426	The St. Raymond Paper Co. Ltd.	$800
First Falls, Mamicouagan River, together with 500 acres of land mentioned in above list.	331,456	A. W. de Torimier.	$2,005 Obligation to expend $500,000 on operating these falls within five years.
Manouan River, Champlain County, together with 50 acres of land. Mentioned in above list.	1,000		$505 Obligation to spend $100,000 on development within five years.
Sault au Cochon River together with 1,318 acres. Mentioned in above list.	2,000		$805 Obligation to expend $150,000 on development within five years.

Reference.—"Report of the Minister of Lands and Forests of the Province of Quebec, 1906."

Further west, is situated Niagara Falls. Three large power stations have been erected on the Canadian side of the Falls, and at present 10,000 H.P. is being transmitted to Toronto, as is discussed in the special section above dealing with Niagara (p. 13).

Sault Ste Marie.

Proceeding westward, the next important water power centre is at Sault Ste Marie, at the head of Lake Huron.

The growth of this place within the last ten years offers perhaps one of the best examples of the rapidity of the development of American towns. Sault Ste Marie is situated at the point where Lake Superior empties itself into Lake Huron, and, like Niagara Falls, two towns have arisen, one on the American, the other on the Canadian bank of the river. In 1897 the town numbered only 2,500 inhabitants, being merely a scattered village with some old flour mills, and chiefly of importance on account of the locks for the passage of the large freight boats taking iron ore from the Lake Superior district towards the east. Five years later, some 6,000 men were employed in the factories, and now a great centre has arisen with steel works, rolling mills, blast furnaces, chemical works, and sulphite pulp mills. This metamorphosis took place as soon as it was realised how important the situation of the place was, and what possibilities lay in the application of the water power available from the Sault rapids in their 20 foot fall. The development of the district is due to the enterprise and energy of Mr. F. H. Clergue, who in 1894, took steps for the harnessing of this large water power. Since then, upwards of £10,000,000 have been expended on this scheme and the accompanying industries.

The minimum available electric power of Sault Ste Marie is about 110,000 H.P., and the present utilisation of power amounts to 60,000 H.P.

The method by which this water power is controlled is by the construction of three parallel canals through the narrow neck of land which separates Lake Superior from Lake Huron. The largest of the canals is on the American side of the boundary, and is 2½ miles long, 200 feet wide and 22 feet deep. The

water, to the amount of 108,000,000 cubic feet per hour, passes into a wide forebay, through and across which is the power house owned by the Michigan Lake Superior Power Co., and which extends over 1,368 feet in length. The turbines, on account of the low available head, number 320, each of 125 H.P. The Union Carbide Co., which adjoins this power house, takes 10,000 H.P. for the manufacture of calcium carbide (p. 31). The two smaller canals are on the Canadian side. Here some 20,000 H.P. was originally developed, but there appeared no means of its disposal, and no manufacturers came forward to avail themselves of it. The Canadian Lake Superior Power Co., as the enterprise was named, had consequently to cast about for something it could manufacture itself. Accordingly, the making of pulp was decided upon, and the Sault Ste Marie Pulp and Power Company was formed and capitalised at £500,000. This at first was most prosperous, and underwent enlargements, but later suffered severely from the competition of the paper makers of the United States, who combined to lower prices. A process for the manufacture of dry pulp was invented, however, and the product is now prepared on an extensive scale.

Next the production of sulphite pulp was taken up for the manufacture of which sulphurous acid is requisite, and the next problem was to obtain sulphur. The source of this material which was decided upon was nickeliferous pyrrhotite, which occurs in the neighbouring Sudbury district. After extensive experiments a process was devised of recovering the sulphurous acid obtained by a roasting process.

Another industry was led on to from this by the problem of the disposal of the residue containing nickel and iron left after the roasting off of the sulphur. An electric furnace treatment was devised by Mr. Sjöstedt which gave a ferro-nickel of very high grade.

Iron Industry.

The smelting of iron ores was next engaged in by the Lake Superior Power Co. The Helen iron mine, the ore of which assays 64 per cent. pure iron, was accordingly secured. Mines of the highest grade ore, and only 12 miles from a harbour on Lake Superior, were later opened up, and thus ore can be shipped to the works at a very low cost.

The Canadian Electro-chemical works was next established for the purpose of manufacturing chlorine and caustic soda, the Rhodin Electrolytic process being installed. This process is somewhat similar to that of the Castner-Kellner, working with an intermediate mercury electrode, a cell of inverted bell form being employed. One hundred and twenty of such cells were in use at these works, taking a total current of 800 H.P. and producing 9 tons of bleaching powder and 4½ tons of caustic soda daily. This plant is now no longer in operation.

Kakabeka Falls.

Still further west, near Fort William, at the head of Lake Superior, a power development has been undertaken at the Kakabeka Falls on the Kaministiquia River, and is being utilised for the supply of current to Fort William and Port Arthur. Between Lake Superior and Hudson's Bay there are known to be extensive water powers not yet developed, and further westward, many occur on the Lake of the Woods.

At Winnipeg, electric power for the driving of trams and lighting the city, etc., has been brought in from falls on the Winnipeg River.

*West Kootenay Power and Light Co.**

This power development is situated in the centre of the mining district of British Columbia, having been constructed at the Bonnington Falls on the Kootenay River. This is a tributary of the Columbia River, and has been found to have a minimum flow of 5,850 cubic feet per second at the above falls, where there is a drop of 70 feet. The natural head is now being increased to the extent of 10 feet by building a timber dam across the river.

The power house is of reinforced concrete built actually in the old river bed, a cofferdam having been constructed from the bank to an island in the river, thus removing the water from the whole site. The water is led to the turbines down a tube formed in concrete without any steel lining. Each 8,000 H.P. turbine consists of three inward flow Francis runners. Half of the water passes upwards, and is brought down again by a draft tube. The lower runner discharges downwards into its own individual draft tube.

By thus discharging in opposite directions the thrust on the bearing is eliminated. The generators, which are of the umbrella type, are directly connected to the turbines, and operate at 2,200 volts and a frequency of 60 cycles. Two units only are at present installed, and two more are in course of erection. The general scheme of electrical distribution is so arranged that power can, at present, be delivered to Phœnix, 79 miles distant, Grand Forks, 69 miles distant, and Greenwood, 83 miles distant, at 60,000 volts, and to Rossland and Trail 28 miles distant, at 22,000 volts.

The whole of the power so far sold is used in mining and smelting work and for the lighting requirements of

* B. A. Ross and H. Holgate. "Power development on the Kootenay River." *Trans. of Canadian Soc. of Civil Engineers* (1907), vol. xxi, p. 149.

mining towns. It is now contemplated to apply the power to the operation of railways in the district.

Vancouver Power Co.

Another important development near the west coast is that of the Vancouver Power Co. at Buntzen, near Vancouver. The water is here led from one lake to another by means of a tunnel in solid rock, a distance of $2\frac{1}{2}$ miles. A head of 420 feet is thus available. 15,000 H.P. are now being developed and sold, and provision for 40,000 H.P. exists. Current for light railways, local industries and lighting is provided by this company.

The Stave Lake Power Co. at Ruskin, near Vancouver, is now erecting a large power plant on Stave Lake, and current will be transmitted from here to Vancouver. The Canadian Pacific Railway contemplate electrifying sections of their railway in this district.

The Consolidated Mining and Smelting Company of Canada, Trail, British Columbia.

This company possesses a number of mines in the Kootenay district of British Columbia, the chief of which, namely, the Josie, Centre Star, War Eagle, and the Le Roi, are at Rossland, which is reputed to be the seat of the most extensive gold deposits known. An important mine known as the St. Eugene, is also worked at Moyie. Lead and copper ores from these mines are smelted at the company's own smelting works at Trail, a town which is about eight miles distant from Rossland. A quantity of ore from other mines is also bought and smelted here. The annual report of the company for the year ending June, 1907,* shows that the gross value of the metals produced during the year at the smelter

* *Engineering and Mining Journal,* March 14th, 1908, p. 557.

amounted to £757,200 of which £331,400 came from ores from the company's own properties.

The Centre Star and War Eagle mines produced 81,788 tons of ore, containing 32,306 oz. of gold, 27,808 oz. of silver, and 1,030,529 lbs. of copper, of a total value of £178,600.

The St. Eugene mine produced 127,645 tons of ore, containing 679,959 oz. of silver and 29,391,389 lbs. of lead, the total value being £342,800. The Trail smelter treated 222,573 tons of ore producing 69,168 oz. of gold, 1,100,221 oz. of silver, 20,383,083 lbs. of lead, and 3,443,310 lbs. of copper. The dividends paid during this year were £100,000 on an issued capital stock of £966,000.

There are, in operation at Trail, five modern copper furnaces and two lead furnaces. The copper ore as obtained from the Josie mine contains:—

Gold	·4 to 1·5 oz. per ton.
Silver	1·0 oz. per ton.
Copper	1·6 to 2·2%
Iron	16·5 to 23·0%
Silica	41 to 50%
Sulphur	8 to 13%

This ore is first roasted and then mixed with a suitable charge of lime, silica, and coke, and smelted to a copper matte and slag. The copper matte contains about 20 per cent. copper in combination with sulphur and all the gold and silver values from the ore, while the slag contains most of the iron combined with silica, and usually as little as ·1 per cent. of copper. This low grade matte is treated a second time in the blast furnace, when more sulphur is removed, causing the iron to pass into the slag as silicate, and leaving a high grade matte, containing about 60 per cent. copper, whilst the slag contains as little as ·2 per cent. of this metal. This

matte is then shipped to Tacoma, on the Pacific coast, to be further treated for the extraction of copper.

The lead ores which are smelted at Trail vary widely in composition, containing :—

Lead	·5 to 25%
Sulphur	7·4 to 17%
Zinc	4·0 to 22%
Silver	·5 to 50 oz. per ton.
Gold	·2 to 3 oz. per ton.

In purchasing lead ores, when a higher percentage of zinc than 10 per cent. is present, a penalty is deducted on account of the deleterious influence of this metal in smelting by the blast furnace. The lead ores are roasted in Huntington-Heberlein furnaces, at a dull red heat, whereby the sulphur is reduced to about 5 per cent., and are then treated in the Heberlein converter, in which, at a higher temperature, the sulphur is reduced to about ½ to 1 per cent.

The ore is then smelted direct to bullion in blast furnaces, two of which are in operation. The lead bullion is run out at the bottom, while the copper present forms a matte containing lead, copper, iron and sulphur, and is run out of the furnace at a rather higher level. The matte is afterwards treated in the copper furnaces to recover the copper.

The bullion produced by the smelting operation is cast into pigs and has the composition :—

Lead	97·9 to 98·4%
Copper	·15 to ·36%
Antimony	·4 to ·7%
Arsenic	·1 to ·3%
Silver	100 to 300 oz. per ton.
Gold	2·5 to 5·2 oz. per ton.

The whole of the bullion produced is refined by the Betts electrolytic process to the amount of 80 tons daily.

Before describing this a brief account will be given of the older methods now in general use for refining lead.

(1) *Cupellation Process.* In this the whole of the lead is oxidised, whilst the rare metals remain behind. The bullion is, for this purpose, melted on a hearth or cupel lined with a mixture of limestone, cement, fireclay and magnesite, or simply with sand and cement. After raising the temperature to the necessary degree, a rapid current of air is blow over the surface and the lead oxidised and removed as litharge, whilst the gold and silver remain behind on the cupel. The oxide has then to be reduced again to metallic lead. This process cannot be economically carried on with lead which contains less than about 8 oz. of silver to the ton.

(2) *Pattinson Process.* This makes use of the fractional crystallisation of the molten lead silver alloy, which is allowed to cool very gradually, when the lead solidifies first and is removed in the form of crystals, while the liquid which remains contains most of the silver. This operation is repeated several times until lead fairly free from silver is obtained, and a rich silver alloy separated which is then cupelled.

(3) *The Parkes Process.* This is the method most commonly in use for refining lead. The process is usually carried out in the following stages:—

Firstly, Softening of the base bullion to remove copper, antimony, etc. For this purpose the metal is melted in a reverberatory furnace which is constructed of fire-brick laid in a wrought-iron pan, the sides and ends of which are protected by water-cooled jackets. The bars of bullion are placed in the furnace and melted down slowly, and by keeping the temperature low, a dross of copper oxide forms on the surface and is removed by skimming off. The temperature of the metal is then raised, when a dross of oxide of tin (and arsenic if

present) forms, which is removed in the same way. On raising the temperature still higher, antimony appears on the surface in the form of black, oily drops, ultimately forming a sheet which covers the surface of the metal. Fine coal or ashes are then thrown on this, causing the dross to thicken, which is then skimmed off. This antimony dross contains a large percentage of lead and is usually worked up into hard antimonial lead which is used for type metal, Britannia metal, etc. The charge is then ready for the next stage of the process—that of *desilverization*.

For this, the metal is run into a large pan and heated to the melting-point of zinc. A charge of zinc, the amount of which is determined by the gold and silver content of the metal, is then added, and the whole is well stirred. An alloy of zinc with gold and silver is formed, which, on cooling, solidifies as a crust or in the form of crystals on the surface. This zinc crust, which contains only a small amount of lead, is removed by means of a perforated ladle, and, after liquation in a small reverberatory furnace to remove any adhering lead, the substance is subjected to distillation to remove the zinc from the gold and silver. Retorts, which hold some 600 lbs. of metal, are used for this purpose, and provided with a vent-hole on the upper side and with condensers lined with a mixture of lime, clay and cement. Distillation begins after heating for about an hour and is indicated by a green flame which appears at the vent-hole. The zinc collects in the condenser and, when no more distils off, the remaining bullion is transferred to the cupel.

The most important temporary loss results from a dross, which forms on the bullion and which consists of an alloy of lead and silver with any copper present, hence the importance of removing the copper as completely as possible at the earlier stage of the process. A certain loss of silver also takes place through volatilisation together with the zinc during the distillation.

The whole of the lead bullion obtained at Trail is refined electrolytically by the Betts process as described below.

Electrolytic Lead Refining at Trail.

In 1902, Mr. A. G. Betts, after a detailed investigation and trials on a large scale, brought forward an electrolytic method for the refining of lead. The essential difference from other electrolytic processes lies in the use of a fluosilicate electrolyte, consisting of a solution of lead fluosilicate with an excess of free acid. This conducts the current well, is easily handled and stored, non-volatile and stable, and is easily prepared from inexpensive materials. Lead fluosilicate is exceedingly soluble, requiring only 28 per cent. of its weight of water for solution. At first difficulty was experienced through the unevenness of the deposits on the cathode by the lead branching out in crystalline growths and causing a short circuit between the electrodes. The addition of a small amount of gelatine, or glue to the bath, however, was found to surmount this difficulty and to cause a perfectly coherent and fairly smooth deposit. The deposited lead has very nearly the same structure as electrolytic copper and a specific gravity of about 11·36—the same as that of cast lead.

This process has now entered into successful competition with the older methods (those of Parkes, Pattinson, etc.) as a means of recovering lead and silver from base bullion. The most important of these installations is at Trail, and others are in operation at Grasselli, Ind., near Chicago, and at Newcastle-on-Tyne (see p. 129).

The procedure at Trail is to first melt the metal in a circular iron tank about 12 ft. in diameter, and by contact with the air, a dross is formed on the surface which carries away most of the copper. By means of a pump and long spout the molten bullion is then

delivered to the anode moulds which are made of cast-iron of the special design of Mr. R. Truswell. Anodes are thus furnished of compact metal and in a form suitable for use in the tanks, and providing for a minimum of waste through metal not immersed in the electrolyte.

The dimensions of the anode are, 30 in. wide, 31 in. deep, and of thickness from $\frac{7}{8}$ in at the bottom to $1\frac{1}{2}$ in. at the top, the wedge-shape being used to facilitate extraction from the mould. Side lugs project at the top to permit suspension from the bus bars into the tank. The weight of each anode is about 400 lbs.

The cathodes consist of thin sheets of refined lead, which are prepared by a device of Mr. J. F. Miller, in which a trough of molten lead is inverted and the metal caused to flow and solidify over an inclined iron plate. The edges of the cathode are then trimmed, forming a thin rectangular sheet of metal of 20 lbs. weight. The top edge is next wrapped round a copper bar for the purpose of suspending across the bus bars. When *in situ* in the bath, the electrodes are insulated, the anodes on one side, and the cathodes on the other, from the bus bars by strips of wood. Good contact is secured on the flat surface of the lug at the other side through the weight of the electrode.

180 tanks are at present in use at Trail, each being 6 ft. 4 in. long, 2 ft. 6 in. wide and about 3 ft. 6 in. deep. These are made of wood bolted together, and coated with tar inside, and are arranged in pairs, side by side, the current passing through the two in series. The 22 anodes, which together weigh 3—4 tons are lowered into position in the tanks by means of a travelling crane and the 21 starting sheets are next placed in between in a similar way.

The passage of the current causes the anodes to dissolve in from 11 to 12 days. After a lapse of 5—6

days, the cathodes are removed and another set of starting sheets inserted, so that two crops of lead are taken from the anodes. A new arrangement is now being introduced however, in which, by the use of rather thinner anodes ($\frac{7}{8}$ in. thickness at bottom to $1\frac{1}{8}$ in. at top), the electrolysis will be conducted with the use of one set of cathodes to one of anodes.

The electrolyte used is of the composition :—

H_2SiF_6	9·5—10·5%
Pb (as $PbSiF_6$) ...	4·5—5·2%
Specific gravity ...	1·13—1·16

and is prepared by acting on fluorspar in presence of silica, with sulphuric acid. The calcium sulphate resulting from the interaction is allowed to settle and the $HiSiF_6$ decanted or distilled off. Any free sulphuric acid present is removed by the addition of the calculated amount of white lead. The electrolyte tends continually to dissolve an excess of lead from the electrodes and to lose its acidity. This is rectified by using the free acid to replenish the electrolyte. A small amount of glue is added to the solution from time to time to cause greater smoothness of the deposited lead. The function of the glue appears to be partly physical and partly a reducing effect, as frequent renewal is necessary.

The solution is circulated from one tank to another by gravity and is then pumped by rubber pumps and along pipes of the same material. Assays are made daily of the electrolyte, and its composition can be controlled by regulating the current density and speed of circulation. Lowering the current and increasing the circulation raise the lead content of the solution.

During the electrolysis, the lead is dissolved from the anode and deposited on the cathode in a more or less nodulated form. The anode slime remains attached to the anode, so that this electrode changes very little in

appearance even after nearly all the lead is dissolved. This is especially the case when the lead contains a large percentage of antimony, when hardly any change of colour is observable.

The usual current density employed is 16 to 18 amps. per square foot, a total current of from 3,100 to 3,600 amps. and 70 volts being supplied to the two parallel sets of 90 cells. The voltage between the electrodes varies from ·28 V. at the beginning of the electrolysis to ·4 at the end. This increase is caused by the resistance of the neutral solution enclosed in the slimes which gradually become thicker on the anodes. The slime contains lead, copper, gold, silver, bismuth, antimony, arsenic, sulphur and occasionally tin, selenium and tellurium, while zinc, iron, nickel and cobalt originally present in the lead pass into the electrolyte.

On the completion of the electrolysis the 22 anodes are removed from the tanks together, and taken into a washing tank where the black slime is carefully removed from scrap metal and freed from fluosilicate. The amount of scrap returned is about 20%. At first the water from a later stage in a previous washing is used, careful note being made of the specific gravity of the different portions of wash water as this is eventually returned to the electrolyte.

The average composition of the slimes is as follows:

Lead	10—18%
Arsenic	23—28%
Antimony	21—27%
Copper	7—22%
Iron	1—2%
Silver	5%

The zinc, iron, nickel and cobalt go into solution in the electrolyte but as they are present only in very small amount, cause little or no complication.

Treatment of Slimes.

It has been a problem of considerable difficulty to devise a satisfactory method of separating the constituents of the slimes and one which has been the subject of a very large amount of experimental work.

Methods which have been proposed for the treatment of slimes include the following:—

(1) A distillation process which is carried out in the electric furnace, effecting separation by the fractional boiling of the metals.

(2) Amalgamation, whereby arsenic and antimony can be separated from the metals which alloy with mercury.

(3) Fusion to alloys and then separating by chlorination or precipitating one metal by another, or by electrolytic refining.

(4) Dry chlorination of the slime, followed by a separation of the chlorides by fractional distillation.

(5) Direct electrolysis with the slime as anode and a suitable electrolyte, or fusion of the slime to an alloy, followed by electrolytic treatment.

None of the above methods have been taken past the experimental stage or applied at all on a practical scale One method of separating antimony which has met with more success, having been in operation at Trail and at Newcastle-on-Tyne, consists in treating the slimes with hydrofluoric acid. Antimony is thus dissolved, and after the addition of some potassium or sodium fluoride, the solution is electrolysed and antimony deposited. The method which is now in use at Trail, however, having been developed to a successful process, is as follows:—

The anode slime is washed on the counter current principle, the wash water which results from a previous washing being first used. When the wash water contains a certain percentage of electrolyte it is returned to the vats to replace losses.

The slimes are allowed to settle after each washing, and the water is removed by decantation. The final washing is effected with hot dilute alkali to remove the last traces of acid, and the slimes are then boiled with a 6 per cent. sodium sulphide solution, containing a little free sulphur. In this way the antimony is dissolved whilst most of the arsenic remains unattacked.

The unaltered slimes are allowed to settle and the supernatant liquid passed hot through a canvas filter into tanks where it is subjected to electrolysis.

For this purpose, 10 cells in two rows are arranged in terraces to allow of fairly rapid circulation of the electrolyte.

The tanks which are about 4 feet deep and 23 inches wide each contain 19 cathodes of sheet iron and 18 lead anodes in the form of thin sheets. These are about 3 ft. 6 in. deep and placed an inch apart. The E.M.F. used is about 1 volt per cell and the current density about 6 amps. per square foot. The bath is kept at about 60°C. of gas. Antimony is deposited to a thickness of about $\frac{1}{8}$ inch and the sodium sulphide is partially converted into the sulphate, while the Antimony content falls from about 1·5 to ·5 per cent.

The deposited metal is removed from the iron cathodes, and, after melting under a flux of antimony oxide and sulphide, gives bars of pure metal which solidify with a crystalline surface of star configuration, which is an indication of their high purity.

The slimes, after extraction with the sodium sulphide solution, are next roasted and the lead is slagged off. The silver and copper are then dissolved out by sulphuric acid which is heated with steam and well exposed to air. Silver is removed from this solution by immersing copper plates, which after the lapse of a few days brings out all the silver as a slime which sinks to the bottom. Copper sulphate is then recovered from this solution by

crystallisation. Further treatment of the residue with sulphuric acid leaves behind the contained gold.

The refined lead is 99·989 % pure. Some is used for the manufacture of lead pipes (¼ in.—3 in. diam.) a process which is conducted in the Refinery at Trail by means of a hydraulic press. The remainder of the lead is cast into bars and transported.

Advantages of the Betts Process.

The chief advantage over the Parkes process is that the electrolytic method does away with the use of zinc and also saves a considerable amount of fuel. Furthermore in fire refining, there is a loss of silver amounting, it is said, to about 1½ %, which is to a large extent avoided in the Betts process. Electrolytic lead is moreover entirely free from bismuth, thus enhancing its value considerably, and is moreover of special value for the manufacture of white lead, as the absence of antimony increases its facility of corrosion. The process also offers advantages from the hygienic standpoint as it is only during the melting and casting of the lead that any danger of lead poisoning is incurred by the workmen.

With regard to the economy of the process, the power at Trail is taken from current supplied by the Bonnington Falls Power Co. at a cost of about £4. 15s. per H.P. year. One ton of lead requires 260,000 amps. hours at an average of ·35 volts, which amounts to 106 electrical H.P. hours. Allowing 10 per cent. loss of efficiency in the tanks and about 8 per cent. loss in the transformer, this makes 120 H.P. hours, which works out to a cost of 1s. 4d. for power per ton of lead refined, the cost of 1 H.P. year being taken as £5.

The successful undertaking of this process is obviously not at all a question of the availability of cheap power, as with coal at £1. 5s. a ton, the cost for power would not amount to more than 2s. 6d. per ton of lead refined.

This fuel consumption is far below that needed in fire refining, and the labour involved, including that demanded by the treatment of the slimes, is no greater than in any of the older methods.

The Betts refining plant at Grasselli, Ind., belongs to the U.S. Smelting and Refining Co., and is somewhat similar to that at Trail. No smelting is carried on but lead bullion containing 10—20 ozs. of silver is imported. The power is generated from steam, an engine of 100 H.P. being used for the pumps and another of 300 H.P. for the electrolysis.

The power expenditure for the output of lead, and also the number of tanks appear to be greater than at Trail.

CHAPTER V.

ELECTRIC SMELTING OF IRON ORES AND STEEL PRODUCTION.

THE electric smelting of iron ore and manufacture of steel is a subject which at the present time is attracting much attention, and it is particularly in this field that the application of electrical methods of heating promises extensive developments. Two distinct lines of progress are observed. Firstly the refining of steel obtained by one or other of the ordinary methods of manufacture, and secondly, the direct reduction of iron ore in electric furnaces, a development resulting from the great success which has attended the use of electrical methods for the manufacture of ferro-alloys.

In the case of steel production, regular commercial manufacture has been carried out during the last few years in several distinct localities, although relatively on a small scale, and here the possibilities of development are apparently in a large measure independent of the source of power, since steam, gas and water driven plants are all in use. Commencing with the task of producing a material of a crucible steel grade at a marked reduction in the cost of manufacture, some of the processes are already extending in directions where the possibilities should offer them a much wider field of usefulness. Despite the scepticism at first met with on the part of the steel manufacturers the processes are now being taken up seriously by many steel works on the Continent and in America.

For the production of iron the case is entirely different; here the prospect of supplementing the blast furnace is, to say the least, very remote in countries where coal is even moderately easily available. But it must not be forgotten that there are important countries in which this condition does not hold, and notably in Canada, where very cheap water power is abundant, there seems a practical possibility of employing electrical methods of heating. The Canadian Government has fully recognised these chances and has subsidised attempts to seriously test the commercial feasibility of electrical iron ore reduction.

Briefly stated, the advantages upon which the electrical methods primarily rely are, firstly, the replacement of a large proportion of the coke in the blast furnace process by heat generated from electric energy, and secondly, in the possibility, in furnaces of relatively simple construction, of attaining higher thermal efficiencies than can be attained without the use of very costly auxiliary plant.

It is well known that the heat efficiency from fuel is as low as 2—3 % in the case of direct heating in forge furnaces, and is from 5 to 10% in apparatus where the heating is effected through refractory walls, as in crucible furnaces, and is from 10—20 % in cupola furnaces of medium height, while maxima of 30, 50, and 70 % are attained in blast furnaces and those of very large dimensions. This low efficiency is due in a large degree to the fact that the products of combustion are greatly diluted with the nitrogen of the air which absorbs large quantities of the heat liberated by the combustion, thus lowering the effective temperature. Furnaces of large dimensions are thus necessitated and consequently the heat losses through radiation from the walls, and by convection are greatly increased. It is obvious how the utilisation of heat developed by the transformation of

electrical energy into thermal energy reduces all these sources of loss.

In considering fuel heating, it must also be remembered that in many metallurgical operations it is necessary to employ fuels, such as coke, which have been treated and hence are more expensive than the original coal. Furthermore, in most cases carbon is not only a source of heat, but also directly or indirectly a reducing agent, and it is not possible to determine exactly the quantity of carbon strictly necessary to furnish heat for the reduction of the ore and that which plays the *rôle* of reducing material, hence an excess of carbon is always added, which in part, is absorbed by the metal it reduces, while the other part causes reduction of other bodies accompanying the mineral. Thus a metal is obtained more or less rich in carbon and containing other metals and metalloids resulting from the reduction of impurities. Impurities are also introduced by the fuel and even from the air necessary to cause the combustion, and these have a harmful effect on the success of the operation.

The Blast Furnace, though it has been brought to such a state of perfection through many years of development, still possesses many disadvantages such as result from the employment of large units, viz., the large first cost, large expenses through breakdowns and the difficulty of repairing, also the difficulty in correcting wrong composition of charges. Further, the nitrogen which is present in the blast of these furnaces has a deleterious effect, imparting brittleness to the iron.

Comparing the relative economies of the Blast Furnace and the Electric Furnace, according to the report of the Canadian Commission, when electrical energy costs £2 a H.P. year and coke £1. 8s. a ton, the cost of production of cast iron will be the same in the blast furnace as in the electric furnace.

*Héroult Steel Process.**

The electric furnace method of preparing steel devised by Dr. P. L. T. Héroult, was brought into operation at the Société Electrometallurgie Française de Froges, and since 1902 a series of carbon steels of the best quality have here been manufactured.

Other installations of the Héroult process in operation are as tabulated below :—

Place	Capacity of Furnace. tons	Approx. Daily output	Power Kw.	Power Expended per ton
La Praz	3	—	300	600—1000 K.W.H. Starting with cold raw materials.
Kortfors	4	—	450	
Syracuse	6	72	500	
Remscheid... ...	2	—	300	180—360 K.W.H.
	3	—	—	when the first part of treatment is effected in gas-fire furnaces.
Sault du Tarn ...	5	—	—	
Baird, California	—	40	—	
Austria—				
Tudenburg ...	3	—	—	
Kapfenberg ...	3	—	—	
Switzerland—				
Schaffhausen...	½	—	—	

In the Héroult furnace the heat is produced in part by the formation of an electric arc above the metal, though principally by the resistance the slag offers to the current. The slag is therefore very hot and active and well suited for the purification of impure metal. The temperature below the arc is very high and the chemical action of purification increases in proportion to the higher

* R. S. Hutton. "The Electric Furnace and its application to the Metallurgy of Iron and Steel." *Engineering* (Dec. 7th, 1906), vol. lxxxii, p. 779.

temperature. The heat in the furnace can be regulated at will, but is usually no higher than in the Martin Furnace. The action of the arc creates a very rapid circulation in the bath and slag, the purification is in consequence very quick and energetic, and a steel containing less than 0·01 % phosphorus can be produced regularly from the cheapest and most impure raw material. The elimination of the sulphur does not take place at this stage, but is brought about by employing an extremely basic slag. The sulphur contents can, in all cases, be brought down to below ·015 %.

In practice, the slags are found to contain calcium carbide which is an indication of the absence of any oxidation. On adding manganese ore, the whole of the manganese for this reason is taken up by the metal without any loss ensuing through oxidation.

At present the most successful development of these methods is at large steel works, where electric furnace processes are used in conjunction with the older methods, and electrical heating is used to supplement ordinary furnace heating. In these so-called "Mixed Processes" the iron first receives a preliminary treatment in the open hearth furnace and from here is poured in the molten condition into a Héroult Furnace to be there subjected to a further and more complete purification.

This method of treatment is especially advantageous for the preparation of alloy steels, as, by avoiding oxidation a large saving in the amount of ferro-alloys to be added results.

In the case of these steels a more homogenous product is said to result from the use of this final electrical heat treatment than with the older methods.

The German works at Remscheid, Germany, operate the Héroult furnace in combination with the Basic Open Hearth Furnace. Only common pig and scrap is used and dephosphorised in the Basic furnace, the hot metal

being transferred to the electric furnace for refining. The time necessary to eliminate sulphur, deoxidise, carburize and to add any metal alloys if required, does not exceed two hours. By this means the best grades of tool steel and any special steels of high quality can be produced economically.

The Héroult Process in America.

A Héroult furnace has been erected at the works of the Halcombe Steel Co. at Syracuse, N.Y. This is a six ton furnace treating a molten charge in two hours. The process has ceased operations temporarily on account of some litigation. A plant for the electric smelting of iron ores by the Héroult process has been erected at Baird, Shasta County, California, near extensive magnetite deposits and water power. This plant is being worked by the Northern California Power Co. Mr. H. H. Noble, in conjunction with the Shasta Iron Co. is taking an interest in the work. This plant was started in 1906, and has been of the capacity of 40 tons of pig iron daily. It is now being contemplated to enlarge to 600 tons daily capacity.

The magnetite ores of Shasta County contain 68—70% iron with little impurity, and are found in conjunction with limestone, which can be used for smelting purposes. Charcoal is used as a reducing agent. Electric energy is obtained from the Northern California Power Co. at the rate of $12 per H.P. year, and in the form of three phase current at 60 cycles and 22,000 volts pressure.

The furnace is elliptical in form and has three vertical carbon electrodes and a neutral electrode formed by the bottom of the furnace. It is estimated that the ore can be converted into pig iron and the latter delivered in San Francisco at a cost of from $15—$18 per ton, whereas imported pig iron is now selling in that city for $30—$35 per ton.

*The Héroult Process in Canada.**

In December, 1903, a Commission, appointed by the Canadian Government, proceeded to Europe to investigate the different electrothermic processes for the smelting of iron ores and the making of steel in Europe. Experiments were conducted and witnessed by the Commission at La Praz, the works of Dr. P. Héroult, and at the works of Keller, Leleux and Co. at Livet in France.

The trials undertaken at the latter works consisted in the reduction of hematite, which had a very low sulphur content. The results showed that a satisfactory yield of iron could be produced with a mean power expenditure of ·35 E.H.P. year per ton of metal. To satisfy the special Canadian requirements, it still remained to be ascertained (1) If magnetite, the chief Canadian ore, and iron ores with high sulphur content, could be successfully and economically treated by the electro-thermic process, and if charcoal or peat coke, which constitute Canadian products, could be substituted for ordinary coke in the smelting process. An experimental investigation of this subject was, at the beginning of 1907, authorized by the Government, and a sum of £3,000 granted for the purpose.

The work was carried on at Sault Ste Marie, Ont., at the works of the Lake Superior Power Co., and with their co-operation. Sault Ste Marie, through its position on Lake Superior, is, as already described, specially accessible to the iron ore deposit of that district, and should prove a very important centre for future electric smelting industries.

The furnace used in these trials consisted of an iron casing, lined with carbon paste, the bottom being connected with one pole. The electrodes used were

* "Report on the Experiments made at Sault Ste Marie, Ontario, under Government auspices, in the smelting of Canadian iron ores by the Electro-thermic process." Dr. Eugene Haanel, Ottawa, 1907.

imported from Sweden, being manufactured by the Héroult process, and of dimensions 16 in. × 16 in. × 6 ft. long. The electrode, with its holder, was supported by a chain passing over a pulley and operated by a worm wheel. Means were adopted to utilise the calorific power of the carbon monoxide developed through the reduction of the ore. For this purpose, an air pipe, provided with holes, was inserted two feet below the top of the furnace, by means of which air for the combustion of the carbon monoxide could be passed in. It was afterwards found however, that the heat developed by this means was so great that the charge in the upper part of the furnace became fused and would not descend into the crucible; also rapid consumption of the electrode resulted.

The furnace charge was made up of ore crushed into small pieces and mixed with limestone and carbon. The carbon used was in the form of briquettes, consisting of a mixture of 80 % coke dust and 20% fire clay.

Careful electrical measurements were made of the volts, ampères, and the power factor. In a typical experiment, the following results were obtained.

Composition of Charge.

Ore	200 lbs.
Coke	60 lbs.
Limestone	30 lbs.

Length of run, 1 hour 40 mins.

Mean volts, 36·5. Mean amps., 4,500. E.H.P., 2,023

Pig iron produced, 264 lbs.

El. horse power year per ton of pig, 0·292.

In subsequent experiments, the carbon lining on the sides of the furnace was replaced by one of magnesite fire bricks, in order to cause the current to pass through the body of the charge.

Ores of high sulphur content could be successfully treated by increasing the amount of lime in the charge.

Smelting of Magnetite.

It was expected that some difficulty would be encountered in the smelting of magnetite on account of its conductivity preventing concentration of heat. In presence of charcoal however, this difficulty was not experienced nor was the inductance of the furnace increased by the presence of magnetite. The use of charcoal as a reducing agent was found to answer admirably, though this was of very poor quality. The charcoal was crushed and added to the charge in lumps not greater than ¾ in. diameter. With regard to the yield of these experiments, under normal conditions about 11·5 tons of pig iron were produced by an expenditure of 1,000 electrical horse power days. With a properly constructed plant on a larger scale this should reach 12 tons.

Cost of production of Pig Iron per ton according to estimate of Héroult:—

Ore at $1.50 per ton	$2.70
Charcoal, ½ ton, at $6.00	3.00
Electric energy, amortization, etc.	2.43
Labour	1.00
Limestone	0.20
18 lbs. electrode at 2 cents lb	0.36
General expenses	1.00
	$10.69

Production of Ferro-Nickel Pig.

At the termination of the above experiments, the Lake Superior Corporation purchased the Government plant, and have since been employing it for the production of ferro-nickel pig. Roasted pyrrhotite is taken for this

purpose (of about 2% sulphur content) and the following charge used:—

Roasted pyrrhotite (2% sulphur)	2 tons.
Limestone	1,500 lbs.
Charcoal	1,200 lbs.
Electrodes	40 lbs.

The resulting ferro-nickel pig has the composition of about 2·7% silicon, 0·01% sulphur, 0·03% phosphorous, 4% nickel, and ·8% copper.

The first electric smelting plant in Canada for the production of pig iron and of high grade steel is at present under construction and located at Welland, Ont., on ground facing the Welland canal. This was first erected by Héroult as a demonstration plant, but has now been taken over by a company who have capitalised it to the extent of $1,500,000.

The first installation will consist of one 3,000 H.P. furnace, which is expected to produce 35—40 tons of pig iron per day. The power will be furnished by the Ontario Power Co. of Niagara Falls. Negotiations are said to be now on foot for the development of a large water power at the Chats Falls, the cost of which is estimated will be as low as £1 per H.P. year (p. 43).

*The Induction Furnace.**

In furnaces of this type, the use of electrodes for introducing the current into the bath of steel has been eliminated entirely, and the advantages claimed are that the objectionable tendency for the introduction of carbonic oxide and impurities from the electrodes has been obviated. The general principle on which these furnaces

* R. S. Hutton. *Engineering* (1906), vol. lxxxii, p. 779.

* *Electrochem. Ind.* (1903), vol. i, p. 576; (1907), vol. v, p. 172. *Elektrotechnische Zeitschrift*, 1907, vol. xxviii, pp. 1051, 1084, 1108, 1124.

work is the arrangement of the bath of molten metal in an annular ring crucible employing this as the secondary circuit of an induced current. A quadrangular iron core formed of thin insulated sheets of soft iron, is placed in the centre of the circle and connected around the outside of the crucible. Insulated copper wire or a water cooled copper tube is wrapped around the arm of the core inside the circle and serves as the primary coil for the alternating current. The current, when passing through this coil, excites a magnetic flux in the core and this flux induces an alternating electric current in the contents of the furnace chamber. The arrangement is consequently that of a step down transformer having a large number of primary turns and a single secondary turn, the secondary turn consisting of the steel in the furnace. The current in the steel is thus about equal to that in the primary circuit multiplied by the number of turns of wire in the primary coil, and the voltage is of course reduced in the same ratio as the number of amperes are increased.

The advantages that this process possesses is the saving of cost of carbon electrodes, which undergo considerable consumption when employed for introducing current. A uniform heating is effected, and the temperature can be easily controlled and raised to any degree, gases are completely eliminated, and by treatment with a suitable slag, all impurities removed. This furnace is very convenient for the introduction of the current, enabling the application of a high tension current without the use of transformers or copper cables of large cross sections. A saving is also affected through the avoiding of losses which follow the use of large alternating currents, when applied directly to resistance heating, on account of induction and through a "skin" effect at the surface of the electrodes. Another advantage of the induction furnace is that fluctuations in the current do not occur as with other types.

The various uses to which induction furnaces have been applied may be classified as follows:—

(1) Steel preparation from cold cast iron and ore, the latter being added in the quantity required to oxidise the carbon.

(2) Steel preparations from molten cast iron direct from the blast furnace and iron ore.

(3) Steel preparation from cold cast iron and scrap steel.

(4) The above mixture, obtaining the molten cast iron direct from the Blast furnace.

(5) Final refining of steel after treatment in a converter or in a Siemens Martin furnace.

The first attempt to apply the induction furnace in industry was made by Ferranti in 1887, but on account of the difficulties of obtaining the necessary electric power, this scheme received no practical application.

In 1890, Colby took out a patent in America for an induction furnace, and in 1899, Kjellin erected the first furnace of this type for the preparation of steel at Gysinge, which next year attained technical importance. The first furnace had a capacity of 78 kilowatts, but was not satisfactory from a commercial standpoint on account of the cooling surface of the walls being too great in comparison to the contents of the furnace, and the cost of repairs being too high.

A second and larger plant was started in 1901, use being made of a water power, and since then the process has worked extremely well. This furnace contains two tons of steel, half of which is drawn off at a time, the remainder being left to keep the current flowing. The output is four tons of steel ingots in 24 hours when charged with cold materials, and the power expenditure 225 electrical H.P.

Current is generated at 3,000 volts and is transformed by means of the primary coil and iron core of the furnace into a current of about 30,000 amps. which passes

through the steel of the secondary circuit. The furnace is charged with a mixture of pig iron, wrought iron, and steel scrap in such proportions as to give the necessary percentage of carbon, and, after heating to a proper degree, the metal is drawn off by tapping through a hole in the wall of the furnace. The product is of a very good quality and is considered to contain less deleterious matter than other steel.

Many modifications of the Kjellin furnace have been devised in order to cause better circulation of the bath and more intimate contact between the metal and slag. In these, a portion of the metal circuit is usually narrowed, or the current caused to pass through a layer of slag in series with the metal.

In 1904, a company was formed in Stockholm to negotiate the Kjellin patents, and this process was soon adopted at the leading steel works in Europe.

The furnaces at present in operation are tabulated below:—

Country.	Place.	Power on Furnace. K.W.	Capacity of Furnace. Kg.
Germany	Volklingen	750	8,500
,,	,,	400	3,000
,,	,,	90	700
,,	Essen	750	8,500
,,	Gleiwitz	175	1,500
Luxemberg	Dommeldin	90	700
Austria	Kladno	440	4,000
,,	Vocklabruck	65	400
Switzerland	Gurtnellen	330	3,800
Spain	Arayo	215	1,500
England	Sheffield	175	1,100
,,	London	60	100
Sweden	Gysinge	175	1,500
,,	Guldsmedhutte	750	8,500
United States	Philadelphia	60	100
Canada	Niagara Falls	150	800
,,	,,	60	100

The power consumption in these furnaces varies very largely with the size of the unit and the nature of the charge. Thus starting from cold cast iron and scrap steel, a 10 K.W. unit will require 2,000 K.W. hours per ton of steel, whereas with a 750 K.W. unit this is reduced to 600 K.W. hours. Taking the metal in the molten state to begin with, from 150—200 K.W. hours suffice for the treatment in a furnace of the latter size.

*Philadelphia.**

An electric steel furnace of the Kjellin type and known as the Colby furnace has been installed by C. J. Russell at the Central Power Station of the Philadelphia Electric Co. and has been in operation since 1906, being run as a station load equaliser. This has a capacity of 200 H.P. and current is supplied at 240 volts, single phase, 60 cycle. The primary winding of the furnace consists of 20 turns of copper tube, cooled by internal water circulation and insulated by sectional layers of heat insulating materials.

The secondary current is, at a maximum, 15,000 amps. at 8·6 volts. The current consumption needed to melt the charge averages about 28 K.W hours and a total of 36 K.W. hours (47 H.P. hours) per 100 pounds of steel is required. Scrap steel and cast iron are treated in this furnace. The duration of each treatment is about one hour. This process has been very satisfactory, and it is now proposed to instal a 5 ton furnace, working at 1,000 H.P.

The first cost of electric furnaces like the above is said to be only from 20—25% of that of gas furnaces of similar capacity, the cost of repairs is much less, and the expenditure for crucibles said to amount to only 4s. to 8s. as against £2—£3 in the gas processes.

* *Electrical Age* (1906), vol. xxxvii, p. 353.

*Stassano Steel Furnace.**

Major E. Stassano, of Turin began, in 1898, a study of the question of the electro-thermic reduction of minerals and particularly of iron ore, and has now devised and erected an electric steel process at Turin in the Artillery Construction Works on behalf of the Italian War Office. The furnace is principally used for the refining of pig iron and smelting of scrap. Three furnaces of 1,000 H.P., 200 H.P., and 100 H.P. capacity respectively have now been erected.

The Stassano furnace is of cylindrical shape, and is caused to rotate during the treatment. Heating is effected by a set of three arcs arranged in the space above the furnace charge. The electrodes are admitted through double walled cylinders, issuing at a slight upward angle from the furnace and fixed by supports. These cylinders contain, support, and guide the carbon electrodes. The carbons are connected by metallic strips to flexible cables which are attached to the collector of the current placed in the lower part of the furnace case. Between the double walls of the cylinder water is circulated to keep the contents cool. A three phase current is used and the carbon electrodes are fed in by a hydraulic appliance. The arc does not come into contact with the iron or slag, and the consumption of the electrodes per ton of steel is said to be only 5 kilos. while in the Héroult furnace it rises to 18 kilos. The consumption of electric energy varies from 1·1 to 1·3 K.W. hours per kilo of steel produced. The rotation of the furnace enables the slag to be expelled, without stopping the current, by opening the tap hole when this is at at the lowest point. A thorough mixing of the charge is also brought about by the rotation.

* *Journ. of Faraday Soc.*, 1906, vol. ii, p. 150. *Report to 6th International Congress of Chemistry at Rome*, 1906, vol. ii, p. 362.

The furnace charge is usually made up as follows :—

(1) 200 kilos of pig iron turnings mixed with sufficient ore to supply the oxygen necessary for removing the impurities of the pig iron, and with the required proportion of lime for the slag.

(2) 200—300 kilos of iron and steel turnings.

(3) 200—100 kilos of iron and steel scrap.

(4) Ferro-silicon and ferro-manganese in the ordinary proportion, to deoxidise the charge and to introduce the required amount of manganese.

The product ordinarily made is steel to be used for artillery projectiles. It is also being endeavoured to apply the steel to the construction of miscellaneous articles which need material of special quality, hence a large variety of casting work is carried on at the works at Turin.

Current is supplied from a Power Company at Turin, being generated from water power. The cost of this is about 45 frs. per H.P. year.

CHAPTER VI.

OZONE AND WATER PURIFICATION.

THE application of ozone to the purification and sterilisation of water promises to be of the utmost value in dealing with certain cases of contaminated water supplies and as a means of preventing infection in localities where plagues and epidemics are prevalent. Repeated experiments have rendered it certain that ozone has very powerful bactericide properties, and that water containing germs need only be exposed for a very brief interval to the action of this gas in order to destroy all the less hardy bacteria or render them incapable of further development. It appears indeed that ozone acts in a selective way and that the more virulent germs, those of cholera and typhus bacilli are the first to be destroyed and none but the harmless species are left.

Water passing through a common sand filter will be deprived of a very large proportion of the microorganisms it may happen to contain before filtration, but even the best filter beds fail to keep back these germs entirely.

With regard to the economy of the process, it has been demonstrated that the use of ozone compares most favourably in point of cheapness and efficiency with all other processes as a means of sterilising water. Moreover, this gas which consists solely of oxygen in a condensed form has no injurious after effects, since, on standing, it changes completely into oxygen, which imparts freshness to the water.

Ozone is best formed by exposing air to the action of the silent electric discharge, which takes place between two adjacent bodies when charged electrically to a high potential. The formation of sparks is prevented by introducing some form of resistance in the circuit. The air must be kept as cool as possible during the period of formation.

Three leading processes, which will be briefly sketched here, are those of Siemens and Halske, Vosmaer, and the Tindal and de Vrise. All of these are now in successful industrial operation.

*Siemens and Halske.**

The system of treatment adopted by Siemens and Halske is carried out at Martinikenfelde, near Berlin, at Wiesbaden, and at Paderborn. The plant at the latter place was installed about 1903 and since then has treated the whole town supply of water to the amount of about 25,000 gallons per hour. The water is, in all cases, passed downwards through towers 16 feet in height and 3 feet in diameter which are filled with broken stone or coarse gravel, while the ozonised air travels upwards and encounters the water trickling through the mass. The undecomposed ozone escapes at the summit of the tower and is conducted into a dryer, and, after further concentration, it is again introduced into the towers.

At the Wiesbaden-Schierstein works, 125 cubic metres of water are sterilised per hour. The engines are of 50 H.P. The ozoniser is constructed after the type of the Siemen's tube apparatus, in which the discharge space is formed by placing two cylinders concentrically one in the other—an outer glass cylinder serving as one, and an inner metal cylinder as the other pole. The apparatus consists of a cast iron case with three parts: a space underneath for the reception of the air and its distribu-

* *Times* Engineering Supplement, Sept. 19th, 1906, p. 299).

tion through the two contained ozonising tubes, a space above for the collection of the ozonised air and a middle compartment enclosed on all sides with the ozone tube passing through. Water circulates through the middle compartment and also inside the inner tube for the purpose of cooling. This inner tube is connected with the high tension current, of about 8,000 volts, and is carefully insulated. The outside case is connected to earth thus enabling the apparatus to be touched without danger Each cell is provided with a window at the side so that when viewed in a well darkened room the blue light of the silent discharge, which is an indication of good working order, can be observed.

Each unit is of rectangular form, requires 1 H.P., and yields from 13·5—27 gms. ozone per hour, according to the dryness of the air and the rate of flow. In case of interruption of the current or of the air supply, as is, for instance, brought about by fracture of the glass cylinder, an automatic device stops the flow of water in the tower and indicates the faulty cell.

Vosmaer Process.

An experimental plant using this process was worked for some time at Nieuwersluis on the river Vecht, near Amsterdam. The capacity of the plant was 2 K.W. and purified 300 gallons per hour. This process has now been installed at Philadelphia by the "Water Improvement Co." and brought to a higher state of efficiency. It is expected that it will be adopted by the City for the purification of 345,000,000 gallons daily; the estimated cost of the installation being $700,000.

Ozone purification should prove of great value in Philadelphia on account of the typhoid epidemics which are at present so prevalent on account of the bad condition of the water. The advantage which the Vosmaer system claims over the Siemens and Halske is that there

are no solid dielectrics between the dischargers. The brush discharge is produced between sharp pointed combs and flat electrodes. The voltaic arc and spark discharges are prevented by a special system of connections. By means of a step up transformer a potential of 5,000 volts is obtained. The current passes through a high tension choking coil, and is connected with the ozonising apparatus after being shunted by a condenser which raises the effective E.M.F. to about 10,000 volts. Air is drawn by means of an air pump through an ammonia refrigerator and passed on in a dry state to the ozoniser.

The ozonising apparatus consists of a number of light copper tubes, each about 3 inches in diameter and 10 feet in length, the tubes being supported at either end in headers (in the manner of an ordinary closed feed water heater), the air discharge pipe from the drying tank connecting with the header at one end of the ozoniser, and the air suction pipe to the air pump with the opposite header of the ozoniser. The pump compresses the air to slightly above atmospheric pressure and delivers it in the bottom of the stand-pipe distributing itself in minute bubbles through the descending water.

In each tube there is a complete set of dischargers, one flat, connected with the tube and earthed, and the other comb shaped, separated from the flat one at a fixed distance by insulating stems and forks made of porcelain.

The water to be treated is pumped from the river, is filtered and distributed to the tops of the sterilising towers, flowing down these it meets with a stream of ozonised air which goes in at the bottom. The towers are about 15 inches in diameter and 35 feet high. The ozone passes in at the bottom through a perforated plate and the water flows out through a pipe at the side. By maintaining sufficient pressure of air, the water cannot pass through the perforated plate, this principle being

the same as that made use of in the Bessemer converter. The sterilising tower works continuously and on the counter current principle.

Results of tests made on Vosmaer plant at Philadelphia. Average figures for 10 daily tests in Dec., 1905.

Organic Matter in Solution. Before.	Organic Matter in Solution. After.	Quantity of Water. Gals. per hour.	Bacteria before Ozonisation.
14·10	7·55	30,300	19,050

Bacteria after Ozonisation.	B. Coli after Ozonisation.	Electrical Expenditure K.W. Hrs.	Rate per million gals. in K.W. Hrs.
29	0	5·7	188

A K.W. Hour costs $^1/_5$—½ cent., so that at the higher figure, the expenditure on electricity for ozonisation is less than an average of one dollar per million gallons treated.

The cost of the Vosmaer process is calculated to be $1.60 for power and about $0.60 for interest and depreciation per million gallons treated. Negotiations are on foot for installing this process for the purification of the whole city supply of water at New York, Pittsburg, and Niagara Falls, in addition to Philadelphia.

Reference.—Report of J. J. de Kinder. United Water Improvement Co., Philadelphia.

Tyndall and de Vrise Process.

This process is in successful operation at Ginneken, near Breda, Holland, and on a larger scale at Paris. It was designed as an improvement on the Siemens and Halske process in that the use of a glass or solid dielectric is eliminated. Spark and arc discharges are prevented by the introduction of a high resistance in the circuit. For this purpose a series of narrow glass tubes about 2 feet 6 inches high are filled with glycerine and arranged vertically at intervals of a few cms. The

current is led in at the top of these by a wire and passes through the glycerine on to the electrodes. These consist of semi-circular copper discs arranged side by side in a containing horizontal copper trough, which is earthed and provided with a glass top to insulate from the leads, and to enable observation of the discharge. The air, after being dried over lime, is passed through this tube under reduced pressure. A potential of 50,000 volts is applied to the apparatus, this being transformed from a 220 volt supply.

The ozonised air is then delivered to the water in the sterilising towers. In the small plant at Ginneken, the water to be treated is pumped from a stream and after careful filtration is circulated through two towers from bottom to top, in series, each tower being 26 metres in height. The towers are fitted with perforated celluloid diaphragms, at intervals of about 1 metre. By this means the gas is divided into small bubbles and intimate contact with the water secured. The output of the plant varies from 20 to 40 cubic metres (or 5,400 to 10,800 gallons) of water per hour, and the power expenditure is as below:—

Ozonisation takes.........	3½ K.W.
Air pumps take............	2—2·5 K.W.
Water pumps take	3 K.W.

Ozone used per cubic metre of water.

Amount available.	Amount used. 1st Ster.	Amount used. 2nd Ster.	Grams Ozone per hour.
1·9	·85	·55	36

Watts in Ozoniser.	Watt hours for Ozone per M³.	For air compress.
5,138	271	243

Water pumps.	Total Watt hours per cubic metre.	Gms. Ozone per K.W. hour.
32	793	6·85

Cubic metres ozonised air per hour.	Cubic metres per hour sterilised aq.
66·2	19

Chemical Analyses.

Amount of alkaline $KMnO_4$ decolourised, measured in milligrams :—

Filtered water, (1) 13·9, (2) 8·9.

Sterilised water (from one tower , (1) 10·3, (2) 9·8.

,, ,, after passing both towers, (1) 9·1, (2) 8·2.

Bacteria	1,100—2,240
Half pure	130— 200
Pure	32— 25

The object in installing the above plant at Ginneken was to provide a supply of pure water to the town. The enterprise is a private one, receiving some concessions from the town and is said to be profitable. The water is supplied to consumers at a fixed rate. Householders pay at the rate of 6d. per cubic metre (220 gallons) and cottages are supplied at a fixed charge of 2d. per week.

The work adjoins the town power station, and the process is run during the period of low demand of power for lighting purposes.

COMPUTED COSTS OF OPERATION OF OZONE PLANTS.

Process.	Hourly Capacity in gallons.	Yield of Ozone in gallons per E.H.P.	Electrical expenditure K.W. hours per million gallons.	Estimated Capital Cost.	Estimated cost per million gallons water including interest on plant and depreciation.
Tindal and de Vrise, Holland	6,000	5·2	1200	—	—
de Vrise, Paris	224,000	—	143	£20,000	£2/5/-
Siemens and Halske	28,000	—	633	—	£5
Schierstein Paderborn	27,500	13—27	—	£10,000	£4/3/-
Martinekenfield	2,200	—	—	—	£3/18/-
Vosmaer Nieuversluis	4,500—6,500	11	606	—	12/6—£1/5/-
Philadelphia Demonstration Plant	30,000	—	188	—	10/-

CHAPTER VII.

GOLD AND SILVER REFINING.

ELECTROLYTIC parting and refining of bullion are carried out at the mints at Philadelphia, New York, and Denver, and the process is also being installed at San Francisco, in addition to being worked at the leading refineries (see page 35).

The old chemical method of refining, which has now been entirely superseded in the States by the electrolytic process, consisted in alloying the gold with 2½ times its weight of silver, and subjecting the mixture to the action of nitric or sulphuric acid. The necessity of using such large quantities of silver for the parting incurred a great expense in the consumption of acid. Moreover, in the United States at the present time, very little silver reaches the Mints since most of the silver refining is carried to a high degree in private plants; consequently for the old parting process it became necessary to make special purchases of silver.

The processes in use at these Mints are briefly as follows:—

(1) Electrolytic parting process for gold and silver as carried out at New York and Philadelphia. The composition of the anodes is generally about 30 per cent. gold, 60 per cent. silver, and 10 per cent. base metal. The electrolyte employed consists of a solution of 3 per cent. nitric acid and 3 per cent. silver nitrate to which a little gelatine is added. A thin silver sheet serves as cathode, and receives a deposit of silver in the form of fine crystals or nodules. A current density of 7 ampères per square foot is used.

The gold remains behind as a hard, black brittle mass, keeping the form of the anode; and to ensure this condition it is necessary that the gold content of the anodes should not be less than 30 per cent. Copper and other impurities pass into the electrolyte. A little silver still remains with the gold at the end of the electrolysis, and is removed by treating the residue with boiling sulphuric acid, or else the gold, which assays 98 per cent., is melted together with a baser alloy to bring the percentage of gold down to 94 per cent., and then is cast into anodes for the gold refining process described below.

A parting process devised by Mœbius and Nobel is worked at Monterey in Mexico.* The doré metal in this case varies in gold content from 2 to 60 per cent., and the amount of base metal from ·8 to 1·5 per cent. The electrolysis is conducted in long shallow tanks, and an electrolyte used which contains 2 to 5 per cent. silver, 1 to 2 per cent. copper, ·2 to 1·5 per cent. lead, and ·2 to 1 per cent. free nitric acid. The cathode consists of an endless silver belt which travels horizontally through the bath and on which the silver is deposited in the form of loose crystals. On emerging from the bath these crystals are brushed off and collected in a receptacle. There is no anode scrap, as the anode dissolves completely, except the gold. The output of this plant is 32,150 ounces per 24 hours.

Another method of parting bullion electrolytically has been devised by W. Thum, and is in use at the Balbach refinery at Chrome, N.J. The doré bars are contained in a cloth case which is supported on a wooden frame suspended in the electrolyte. Electrical connection is made by a silver contact piece which rests on the bullion.

The cathode consists of graphite slabs placed on the bottom of the tank. Each tank has a cathode surface of 8 square feet and a current density of 20 to 25 ampères

* A. G. Betts. *Lead Refining by Electrolysis*, p. 149.

per square foot is used. The voltage averages 3·8 per tank. Silver is deposited in a spongy form, while the gold remains behind as a slime in the wooden frame.

The advantage of the electrolytic parting of bullion is that the silver is freed from gold and tellurium in one operation, enabling the deposited silver to be melted and poured into bars without any further refining as in the sulphuric acid process. The silver placed in the tanks as anode is refined without any handling, whereas in the acid method, the silver must be submitted to several operations before it is in a condition to be melted. Hence an electrolytic parting plant can be worked with much more neatness and cleanliness than is possible with acid parting.

(2) *Gold refining process.* The electrolytic process now in use was devised about 1878 by Dr. Emil Wohlwill and is still worked under his direction at the Deutsche Affinerie at Hamburg; it was introduced into the United States by Dr. D. K. Tuttle, of the Philadelphia Mint, and with certain modifications, which he has found advantageous, is now worked in that country on a relatively large scale.

The chief disadvantage of the electrolytic process lay in the slowness of the process in comparison with the acid parting methods, by the latter it is possible to obtain from bullion the whole content of gold in the refined state within 24 hours.

By working with a higher current density Dr. Tuttle has been able to increase the speed of the electrolytic process so that, at the present time, it is possible to obtain from 80 to 90 per cent. of the gold in the refined form within 24 hours.

An electrolyte of chloride of gold and hydrochloric acid solution is taken and the bath maintained at 50°—55°C. By keeping sufficient acid in the bath and the correct temperature no evolution of chlorine occurs at the anode. A current density of about 10 ampères per sq.

decimeter and a potential difference of 0·8 per volt per cell is employed.

Pure gold is deposited on the cathode, copper and platinum pass into solution and silver, iridium and osmium-iridium, if present, remain on the anode or fall to the bottom of the vat as anode slime. The recovery of platinum, though only present in small quantities, is thus made quite easy, as it accumulates in the electrolyte and, when sufficiently concentrated, can be precipitated with potassium chloride.

The anodes are, in the latest arrangement, suspended in the bath by platinum hooks, thus completely submerging the gold.

The cells are arranged in sets of six, which are electrically in series; each cell containing four anodes and the same number of cathodes in parallel arrangement and placed longtitudinally. The leads consist of gold wires, the same wire which is connected to the cathode in one cell is continued and acts as positive lead to the next cell. In this way all soldered joints are avoided. The same electrolyte can be made to serve for about two months by replenishing from time to time with concentrated chloride of gold.

A little gelatine is added to the electrolyte to cause smoothness of deposit.

The total capacity of the gold refining plant at Philadelphia is 48,000 oz. a week and a current of 1,500 ampères at 15 volts is used. A new cell room is now being fitted up as a further extension.

At New York these processes are worked in a similar manner, the output being 22,000 oz. of gold weekly, and the current consumption said to be 150 amps. at 14 volts.

REFERENCES.—*Electrochem. Ind.*, **1903, vol. i, p. 157.**
„ „ **1904, vol. ii, p. 221—261.**
„ „ **1906, vol. iv, p. 306.**

CHAPTER VIII.

ELECTRICAL MANUFACTURE OF CARBON BISULPHIDE.

THE commercial application of the electric current for heating purposes is by no means limited to such high temperatures as exceed the range obtainable with ordinary fuel combustion.

Electrical heating has already found successful applications in carrying out chemical processes which were hitherto conducted with the aid of external heat from some combustible fuel. The advantages of the electric current in this field lie chiefly in the possibilities of generating the heat just where it is required and in the facility of regulating the temperature.

The efficiency of fuel heating processes in which the heat has usually to penetrate a furnace lining and a considerable thickness of material, is in many cases very low. In electro-thermal processes, on the other hand, heat is generated in the body of the material which is to undergo chemical change, being led there without any appreciable loss of power, in the form of the electric current. Hence, by suitable outside insulation, the heat losses through radiation may, in practice, be reduced to a very low value, or the heat may be almost completely utilised in raising the temperature of the raw material to the degree necessary for the subsequent reaction. Again, in chemical processes which take place at a high temperature, and which absorb a large amount of heat, if the heat is provided from a source only slightly above the critical temperature of reaction, then only a small proportion of the energy supplied can be utilised in the

chemical change, whereas, with electric heating, the conditions can be made much more favourable.

The manufacture of carbon disulphide is an instance of the successful application of the electric furnace to a process which was formerly carried out with fuel heating, the temperature of the reaction being well within the limits of such heating. This substance is formed by the action of coke or carbon on sulphur at a red heat, and was formerly prepared by heating these materials together in small retorts and condensing the carbon disulphide as it distilled off.

The manufacture on a large scale involved the multiplication of retorts, as these necessarily had to remain limited in size, on account of the difficulty of causing the heat to penetrate. The shells are also easily destroyed by the heat; and their replacement and the constant attention required by a large number of retorts involved great expense.

The electric furnace process of manufacturing carbon disulphide was designed by E. R. Taylor and installed by him at Penn Yann, N.Y. This is the largest electric furnace at present in use, being some 30—40 feet high, and is of stack form, the diameter decreasing slightly towards the bottom. The raw materials are charcoal and sulphur, the latter fuses and remains at the bottom extending as far up as the electrodes. The current is led in by short carbon bars (the amorphous variety), which pass through closure plates and packing glands, and inside these are connected with a layer of broken pieces of carbon or coke to serve as a resistance, which becomes heated by the passage of the electric current. The whole body of the furnace is filled with charcoal. In the path of the current a very hot zone is formed surrounded by regions of gradually decreasing temperature. Volatilisation of the sulphur occurs and the vapour traverses the heated carbon, and in ascending, eventually finds a region in which the temperature is most favourable for

the formation of the carbon disulphide, which then passes off as a gas. On the outside of the stack of charcoal there is a narrow annular space filled with sulphur. Heat, which tends to radiate away, is here employed in melting the sulphur, causing it to flow into the compartment underneath. The control of this furnace is quite automatic, as if the heat becomes too intense, more sulphur melts and rising up around the electrode surface cuts down the current on account of its insulating properties. Consequently the only labour involved in running this furnace is that of feeding the stacks periodically with sulphur and carbon, and a run of a year's duration without any other attention is usually possible.

The furnaces work with about 400 amps. at from 50 to 70 volts, 4 phase alternating current, amounting to a power of 250 H.P.

To condense the carbon disulphide, the furnace gases are passed through a row of tubes, arranged vertically in a cylinder through which water circulates, and any gas still uncondensed is next passed over charcoal and thus absorbed. For this purpose, use is made of the charcoal which is later to be employed in the furnace, and the gas is passed over it while it is undergoing a drying treatment by heating. Some sulphuretted hydrogen is liberated in this operation on account of the presence of water. Means are now being considered of absorbing this gas with iron oxide.

The plant at Penn Yann is ideally situated, having, on one side a water power, and on the other a railway siding. A fall of 32 feet in the river is available, and the water is led from the reservoir above through a steel flume 8 feet in diameter and 50 feet long to the turbines.

The electric current is supplied by two 330 kilowatt, two-phase, Stanley induction generators, which, at the present time, only run at about half their rated capacity. Three furnaces have been built, but only one is run at a

time. An output of 8,000 pounds is produced per 24 hours. Mr. Taylor considers there is no limit to the size of the furnace possible, and that still greater economy would be achieved when working on a larger scale.

The carbon disulphide is loaded directly into special cylindrical tank cars, brought along the railway siding, the liquid being delivered through a short pipe line to the car.

Carbon disulphide is a liquid which now finds considerable application in industry as a solvent of rubber and sulphur and on account of its property of destroying bacterial and other noxious forms of life, and latterly it is being employed as an ingredient in the manufacture of artificial silk (Viscose). The electric furnace process may be looked upon as a decided advance in the manufacture of this material. With this method of manufacture no escaping fumes of any kind are apparent, in spite of the objectionable odour of the liquid and its dangerous inflammatory properties, and the amount of labour is certainly reduced to a minimum, as the whole installation only requires the attention of two or three men during the day and one or two during the night.

This plant supplies the whole demand of the States for carbon disulphide.

CHAPTER IX.

ELECTRO-CHEMICAL INDUSTRIES IN THE ALPS, FRANCE, AND BELGIUM.

THE French Alps contain a large number of hydro-electrical installations, most of which have been applied to electro-chemical enterprises. Developments of water powers from falls in this district, and also in the Pyrenees are increasing very rapidly.

According to the Report of the British Consul at Lyons, the water power used for the various chemical industries in 1906 amounted in the aggregate to 100,000 H.P., whilst, according to Girod, the power used in France in 1906 for the production of ferro-alloys amounted to 50,000 H.P., and the value of the yearly output was £1,200,000.

The production of aluminium in South-Eastern France has made rapid strides, having risen from 1,647 metric tons in 1904 to 1,905 metric tons in 1905, whilst in 1906 the export increased by over 50 per cent. as compared with the previous year (vide p. 30). The extraction of bauxite, the raw material of aluminium, also rose from 75,000 metric tons in 1905 to 103,000 in 1906.

*Valley of Arc.**

At Modane there is a fall of 7 metres on the Arc and one of 135 metres, giving 400 H.P., on the Charmaix River. These two falls are utilised by paper works, which, however, have recently been destroyed by the flooding of the Charmaix River.

On the way from Modane to La Praz there are two

* *Journal d'Electrolyse*, Aug. and Sept., 1906, Nos. 240-243.

falls. The first is 33 metres high and is led through a pipe 2 kilometres long and 2 metres in diameter. The second is 75 metres high. These are used by the Société Electrometallurgique française for the production of aluminium and steel. This company also owns the Bissorte Falls, which have a capacity of 10,000 H.P., and which will probably soon be developed.

About a mile below La Praz, the "Société d'Electrochemie" has a chlorate works and makes use of a water power providing 4,000 H.P.

Still lower down, the Arc widens into a lake which serves as the intake of another power station, at the village of Saussaz. The fall is here 75 metres, and provides a total power of 15,000 H.P. This is also owned by the Société Electrometallurgique française, the power being employed in a second large aluminium works.

At St. Michel de Maurienne there is another fall of 22 metres awaiting development, and the rights of this belong to works in Grenoble.

Further on, at Calypso, the Arc is joined by the Valloirette, and two falls here furnish power to the amount of 11,000 H.P., which is used by an aluminium works belonging to the "Société des produits chimiques d'Alais et de la Camargue." These works contain 10 centrifugal turbines, each of 1,400 H.P., working at 400 revolutions and connected with dynamos of 1,000 K.W. These works were originally erected for the manufacture of calcium carbide, and, in the future, if the demand for aluminium slackens, the production of ferro-alloys and steel will doubtless be undertaken.

At St. Julien, a dam is being constructed and a further power on the river is being developed to the amount of 7,500 H.P. under considerable engineering difficulties, and at a cost of more than a million francs. This is being worked by the Société des Produits chimiques d'Alais" at St. Jean de Maurienne. There are thus, in

all, five aluminium works in the valley of the Arc and one chlorate works in addition to several other electro-chemical plants.

Société Electrometallurgique Française.

This important company works the processes of Dr. P. Héroult and possesses several works. At Froges and at Champ (Isère), at La Praz and at St. Michel de Maurienne (Savoy) and at Gardanne (Bouches du Rhone). The works at La Praz utilise about 13,000 H.P. developed from water power, and that of St. Michel de Maurienne about 17,000 H.P. The company manufactures aluminium and also steel, and in addition ferro-chrome, ferro-silicon and other ferro-alloys.

The steel is prepared in shallow furnaces which are provided with a spout and can be tipped. Two carbon electrodes pass through the arched roof, and the furnace is supplied with direct or alternating current which enters by one of the electrodes, passes through the metal bath through the layer of slag and along to the other electrode.

The process of manufacture consists in taking a mixture of cast iron and scrap steel and iron ore, together with a suitable slag whereby the bath is decarburised. When the oxidation is finished the slag is removed and replaced by another of lime or fluor spar; this operation is repeated as many times as is necessary for complete purification. The metal is then recarburised to the necessary degree by plunging the electrodes in the bath, or else by adding " carburite." The process is finished by the addition of ferro-silicon, chromium, manganese, etc., according to the type of steel required. The consumption of energy in the trials made by the Canadian Commission starting with cold raw materials amounted to from 720 to 1,100 K.W. hours per ton of

steel. The number of operations may be as many as three every 24 hours. The cost of the process amounts to from 29 to 38 francs per ton of refined steel, and is made up as follows:—

Electrodes, 1 franc; repairs, 7 francs; slags and materials added, 3 francs; power, 18—27 francs according to the quality of steel. The cost of power is calculated on a basis of 2·5 centimes per K.W. hour.

*Girod Ferro-Alloy Works.**

This company, known as the Société anonyme Electro-métallurgique, has at present three important works, at Ugine in Savoie, at Courtepin, and at Montbovon in Switzerland. A total of 18,000 H.P. is in use, and harnessing of further power, which is now progressing, will soon render available some 45,000 H.P. In 1898 M. Paul Girod devised a process for the production of high grade ferro-alloys, and in 1899 started a works employing 1,000 H.P. at Albertville.

This work was soon extended on a much larger scale, the great success which followed, being due in a large measure, to the development of high speed tool steels and other special steels.

In 1903, the works at Courtepin were started with 1,800 H.P., the power being obtained at 16,000 volts from the Fribourg Cantonal Government.

In the same year the water rights of the falls of the Arly were purchased, and the installation of the power plant of 8,500 H.P. at Ugine was completed and made available for use within a year.

The furnaces at Ugine are of the "smothered arc" type, provided with automatic regulation and equipment necessary for continuous working.

* R. S. Hutton. "The Girod Ferro-alloy Works and the New Girod Steel Furnace." *Electrochem. and Metall. Ind.* (1907), vol. v, p. 9.

The present annual output of the three installations may be summarised as follows:—

5,000 tons ferro-silicon (50 per cent. silicon).
1,000 tons ,, (30 ,, silicon).
2,000 tons ferro-chromium.
800—900 tons ferro-tungsten.
About 50 tons ferro-molybdenum.
5—10 tons ferro-vanadium.

Other metals produced and put on sale are pure vanadium, titanium and ferro-titanium, ferro-manganese, cupro- and nickel-vanadium, silico-chromium, silico-manganese, ferro-boron, ferro-tantalum, ferro-uranium, cupro-silicon, etc. The total value of the alloys sold at the present time is equivalent to over 9,000,000 francs per annum. The company specialises largely in high grade alloys of low carbon content.

A copper vanadium alloy was exhibited by this company at Liège in 1905. This is prepared in large quantities, and used in the manufacture of articles needed for artillery purposes.

Ferro-chromium is made of very varying composition according to the use to which it is to be applied. For iron sheathing and projectiles an alloy of 65 per cent. chromium, 8 to 10 per cent. carbon, and 2 to 6 per cent. silicon is taken. For crucible tool steels an alloy with a lower percentage of carbon, viz., from 4 to less than 1 per cent. is taken. This latter kind is so soft as to be almost forgeable.

The percentage of sulphur is always less than ·03 per cent.

With regard to the ferro-tungsten, this is made in two grades. The one containing about 85 per cent. tungsten and a maximum of 0·5 per cent. carbon, is chiefly employed in the manufacture of crucible tool steel. The other quality, containing 60 to 70 per cent. tungsten and 2 to 3 per cent. carbon, is largely used in the preparation,

by the open hearth process, of steels containing less than 2·5 per cent. tungsten, which are used for the manufacture of springs, etc.

It has been shown by repeated trials that steels made with ferro-tungsten are more economical and also of a more uniform quality than those made of tungsten powder. The ferro-alloy is, moreover, in a more convenient form for introducing into the steel than pure tungsten.

The ferro-tungsten is sold on the basis of pure tungsten, and the selling price is about 20 per cent. less than that of tungsten powder.

Ferro-Alloy Works of Keller, Leleux and *Co.**

This company has two works, one at Kerrouse (Morbihan), and the other at Livet (Isère). The works at Livet makes use of a total power of 15,000 H.P., furnished by a fall of water 60 metres in height, and the works at Kerousse uses a fall of 2½ metres, generating 600 H.P.

The monthly output of the two works amounts to 250 tons of ferro-silicon containing from 25 to 75 per cent. silicon, 150 tons of silico-spiegel, 80 tons of ferro-chromium, and some ferro-tungsten.

Manganese alloys containing 38 to 40 per cent. manganese, and 22 to 24 per cent. silicon are also prepared.

Ferro-chromium alloy is produced to the extent of 80 tons per month, and ferro-tungsten is prepared at intervals, the total production of the two works amounting to about 100 tons per month. This company has also engaged largely in the production of iron and steel.

* *Bulletin de la Société Belge d'Electriciens* (1905), vol. xxii, p. 645.

The hydro-electric equipment at Livet includes three types of machines:—

(*a*) Low tension, 5 groups monophase generators of 1,200 H.P. Neyret turbines and Thury alternators.

(*b*) High tension, 3 groups of three phase machines of 2,700 H.P. (Bouvier turbines, Brown-Boveri alternators).

(*c*) Direct current, 4 generators of 150 H.P. to supply the motors and accessories of the works.

The low tension current is led directly to the Keller furnaces, which are of the resistance type. The furnaces have each a capacity of 1,200 H.P., and make a melt of ferro-alloy of 500 kilos. each two hours. The high tension current supplies, by means of transformers, three furnaces of a total capacity of 1,500 kilowatts, which furnish a daily output of 12 melts each of 1·2 tons.

A model of a furnace of the multiple type was exhibited at the Liège Exhibition in 1905. This furnace consists of four columns which are in electrical connection by means of a crucible placed at the base. This crucible also serves to collect the molten metal as it forms. The tall columns are filled with the charge to be smelted, which here surrounds the carbon electrodes. Two electrodes are joined in parallel forming two groups, and the current is caused to pass from one group through the charge in the furnace and that in the crucible underneath, to the other group of two.

The furnace works continuously, and the electrodes last about a month, and can be quickly replaced without disturbing the process.

The works at Livet do not engage in the manufacture of cast-iron except on an experimental scale.

Société d'Electro-Chimie.

This company possesses important works at St. Michel de Maurienne, and at Vallorbes, and engages principally

in the production of chlorates of sodium and potassium, The annual output is about 1,500 tons.

The Société d'Electro-chémie also prepares sodium peroxide to the amount of 200 tons a year. This is obtained by passing a current of air over sodium contained in a platinum tube which is heated electrically.

Sodium peroxide finds application in the bleaching of linen and wool. By compressing this peroxide with a salt of copper, a product known as "oxylith" is obtained. This is used for the preparation of oxygen, which is evolved on contact with water.

"*Société Anonyme des Forces Motrices et Usines de l'Arve.*"

The works of this company are situated at Chedde (High Savoy), the manufacture of alkali chlorates being engaged in. Energy to the extent of 13,000 H.P. is consumed for this purpose and is obtained from a water power. In 1904 the output amounted to 4,030,000 kilos.

"*Le Carbone*" *Company of Levallois Perret, France.*

This company prepares all kinds of carbon for electrical purposes, such as lighting carbons, carbons for microphones, for electrodes in electro-chemical and electro-metallurgical work, and battery carbons. Machines are in use which enable the construction of carbon articles in all shapes. For these purposes, amorphous carbon, such as gas coke, is ground to a fine powder, mixed with a little binding material, such as tar, pressed in a hydraulic press or squirted through dies, and then baked in a furnace, whereby a solid agglomerated mass results (compare page 21). For some purposes, such as for electrodes, the carbon articles are heated to a much higher temperature and graphitised.

The graphitising furnaces are of the form designed by Girard and Street, and consist essentially of a closed

chamber, through which the carbon articles are slowly drawn by means of rollers and caused to pass through an electric arc, which plays inside the chamber between two transverse electrodes.

In this apparatus the power consumption is found to be 7·36 kilowatt hours per kilogram of carbon transformed.

The Carbone Company possesses three works, at Levallois-Perret (Seine), at Notre Dame de Briançon (Savoy) and at Frankfort-on-Main.

These three works employ a total motive power of 750 H.P., of which 500 H.P. are derived from water.

Electro-Chemical Industries in Belgium.

Electrolysis of Water—" La Société Oxyhydrique."

Some 20 processes for preparing hydrogen and oxygen by the electrolysis of water have been patented, and some of these have been brought into industrial operation.

The one which is most widely in use at the present day is the apparatus of Garuti which was brought out in 1893, and which has undergone several modifications.

Garuti introduced the use of metallic plates as partitions between the anode and cathode compartments. Previously their use had been avoided on account of the risk of their acting as bipolar (intermediate) electrodes, and evolving hydrogen on the side towards the anode, and oxygen in the cathode department. Diaphragms were consequently constructed of linen, cotton, asbestos cloth, parchment paper or vegetable fibres. The electrolytic decomposition of water requires approximately 1·5 volts, consequently, if a separating partition is to act as an intermediate electrode, an E.M.F. of 3 volts will be necessary. By raising the partition so as to allow the fluids to communicate by a passage underneath, electrolysis will begin

at 1·5 volts, and by keeping this below 3 volts there is no possibility of the partition taking part in the electrolysis.

In the Garuti process, the electrolysing apparatus consists of an iron rectangular box, open beneath, and divided by metallic plates into long, narrow, divisions. The electrodes are introduced into the chamber thus formed by means of a wooden comb which serves at the same time for insulating the electrodes from each other and the metallic partition. The electrodes are placed at a distance of 12 mm. from each other. The partitions have a zone of fine perforations which, in the latest modifications, are placed at the level of the middle of the electrodes. The container is dipped into the electrolyte in the manner of a gasometer bell. This holder is provided with outlets for the gases and hydraulic seals to prevent mixture of the gases by not allowing any increase of pressure in the apparatus. The gases are led away to a pump and compressed in steel bottles.

A current density of 2 amps. per square centimetre and an E.M.F. of 2·45–3 volts is used and an electrolyte of caustic soda, 21 Beaumé, or caustic potash, 16–18 Beaumé, is taken. The resulting hydrogen has a purity of 98·5 per cent. to 98·9 per cent., and the oxygen 97 per cent.

"*La Société Oxyhydrique*" was formed at Brussels (Molenbeek) in 1896. At first difficulty was met with on account of the small market for hydrogen and oxygen. Attention was then turned to the designing of an oxyhydrogen blowpipe which has now established itself as a valuable implement in industrial work, being used for working metals. Another new application found by the company for oxygen is for the cutting of sheet iron, which is brought about by local fusion.

The works at Brussels contain 100 Garuti elements, which are mounted in series, and which consume 124 kilowatts, under a difference of potential of 240 volts. The annual output is 140,000 cubic metres of hydrogen

and 70,000 cubic metres of oxygen. A second works is now being erected at Sclessin. Other works using the Garuti process are at Schiedam, Montbars, Lyons, Lille, Lucerne, Thale, Paris and Rome.

The plant at Schiedam has a daily output of 360 cubic metres of the mixed gases, 80 H.P. being consumed in the electrolysis, and 20 H.P. in the compression of the gases.

In the installation at Rome, power is received at about £3 per H.P. year, approximately $^1/_{10}$d. per unit. This corresponds to a cost of 1·3d. per cubic metre of the mixed gases. Allowing for depreciation of plant and interest on capital, the cost has been estimated at 2¼d. per cubic metre of the mixed gases.

Hydrogen is obtained as a bye-product in electrolytic processes for the production of alkali in which aqueous solutions are used. In these processes large amounts of this gas have hitherto been allowed to go to waste. Latterly, however, methods of collecting it have been adopted in some cases, the gas being led away and compressed in steel cylinders. Some use has been found for electrolytic hydrogen in Germany for balloons, the high purity of the gas and its consequent lightness making it specially suitable for this purpose.

Solvay Company.

The Solvay Company operates a process similar to the Castner-Kellner for the electrolysis of salt solution and production of chlorine and caustic soda.

A works has been erected at Jemeppe sur Sambre using 1,000 H.P. The purity of the caustic soda is said to be very high, allowing it to compete with that obtained by alcohol.

CHAPTER X.

THE ELECTRICAL FIXATION OF ATMOSPHERIC NITROGEN*

THE question of the source of nitrate supplies in the near future is a subject of great economic importance. Up to the present the only known extensive deposits of nitre are those of Chili, and, as the demand for this material as a fertiliser is rapidly increasing in order to meet the needs of a growing population, and on account of more intensive cultivation of land generally, exhaustion of these natural deposits at no distant date appears to be inevitable.

The necessity of applying large quantities of nitrate to the soil for agricultural purposes, to replace that which is abstracted by the crops, is now generally recognised by agriculturalists. It is estimated that in France alone the quantity of nitrogen removed from the soil by the crops annually amounts to 600,000 tons, whereas 230,000 tons of Chili saltpetre are yearly consumed to make up the loss.

In consequence of this, the artificial production of nitrates has suddenly gained a very important place among technical problems.

It is to the atmosphere that attention has been turned for the supply of nitrates in future, and, it is indeed estimated that out of the air over each square mile of the earth's surface, more saltpetre can be made than is to be found in all Chili. The possibility of causing the union of nitrogen and oxygen was first discovered by

* Kr. Birkeland. *Trans. Faraday Society*, vol. ii, p. 98 (Dec. 1906).

Cavendish as early as 1785. These gases were found to combine under the influence of the electric spark, yielding oxides of nitrogen, which are readily transformed into nitrates.

This method was made use of by Rayleigh as a means of separating nitrogen from the atmosphere, in the important work on the preparation of argon.[1] McDougal and Howles [2] were the first to carefully work out the industrial application of the electrical fixation of nitrogen. By employing a high tension alternating arc in air they succeeded, by a study of the necessary conditions, in obtaining a yield of 300 grams nitric acid per 12 H.P. hours, in this way combining 51 per cent. of the air passed through their apparatus, whilst with a mixture of two volumes oxygen to one volume of nitrogen the yield rose to 590 grams per 12 H.P. hours.

This subject was next taken up with more favourable results by Bradley and Lovejoy at Niagara Falls.*

The aim of all this work was to obtain electric arcs of the greatest possible length so as to bring the arc in contact with the maximum amount of air and also to provide for sudden cooling, once the products of combustion had formed.

In the apparatus employed by Bradley and Lovejoy a rapid interruption of the arc was provided by means of a rotating framework with projecting electrodes. These approached a stationary set of projecting electrodes of platinum at frequent intervals, and an arc was thus formed, drawn out, and rapidly broken.

A wholesale synthetic production of nitric acid from air was attempted by means of this apparatus of Bradley and Lovejoy. A company known as the Atmospheric

1. **Rayleigh.** *Journ. Chem. Soc.*, vol. lxxi, p. 181 (1897).

2. **McDougal and Howles.** *Manch. Lit. and Phil.*, vol. xliv, part 4, No. 13, pp. 1—19 (1900). **Hutton and Petavel.** *High Temp. Electrochemistry Inst. Electr. Engineers, Manchester Section*, Nov. 25, 1902.

* **Bradley and Lovejoy.** *Electrochem. Ind.* (1903), vol. i, pp. 20, 100.

Products Co. was formed, and a small trial factory built at Niagara Falls. This undertaking did not meet with success, however, probably on account of the apparatus being rather complicated, and the cost of erection and maintenance per kilowatt being disproportionately large.

Work on the formation of oxides of nitrogen was next taken up with greater success by Birkelande and Eyde, who introduced the use of a special form of high tension flame obtained by placing an alternating current arc equatorially between the poles of a powerful electromagnet. An electric disc flame is thus produced consisting of a series of arcs, which follow one another in quick succession, extend rapidly outwards in the form of a circle, and finally break. The discharge has thus the appearance of a completely luminous circular disc, and is of a very high efficiency for the combustion of the nitrogen. The electrodes consist of water cooled copper tubes, placed about 1 cm. apart, the cooling effect of which, as measured by experiment, causes a loss of only about 7·5 per cent. of the electric energy.

In the Birkeland-Eyde process this alternating current disc flame, which measures about 6½ feet in diameter, is enclosed in a special narrow furnace lined with fire-brick and furnished with a metal casing.

This process is now in successful operation at the Nottoden Saltpetre Manufactory, where a number of these furnaces are in use, each employing 500 kilowatts (670 H.P.).

These furnaces run quite automatically, and can be left without attention for long intervals. Roaring of the flame takes place when readjustment of the electrodes is needed. A working potential of about 5,000 volts is used, and variations in energy do not exceed 2–3 per cent. Though the temperature of the flame is somewhere near 3,000°, the fire-brick lining of the furnace does not rise above 700°C. during normal working on account of the cooling effect of the current of air.

The products of the furnace consist of nitric oxide mixed with a large excess of air. After cooling, the nitric oxide combines with more oxygen from the air to form nitrogen peroxide which unites with water to yield nitric and nitrous acid.

An absorption system of stone towers is arranged to condense the fumes. A solution of nitric acid of 50 per cent. concentration is obtained in the first tower, and more dilute acids in the others, the counter current system of water circulation being adopted. The nitric acid solution is neutralised by lime, and after evaporation to dryness the calcium nitrate can be applied directly as a fertiliser.

A solution of milk of lime is placed in the last absorbing tower, and the acid absorbed in this forms a mixture of nitrate and nitrite. This is quite unsuitable for use as a fertiliser, and, in fact, is decomposed by nitric acid from the other towers, and the gases are put back again into the system.

A number of agricultural experiments have shown that calcium nitrate is quite as good as the natural saltpetre for fertilising purposes, and on sandy soil even superior to it on account of the valuable properties of the lime.

As air contains a considerable excess of nitrogen above that needed for the formation of nitrogen peroxide, it has been proposed to enrich the reacting mixture by the addition of an excess of oxygen. The increase of yield obtained by using the theoretical amount of oxygen in this manner is said to amount to 20 per cent. Oxygen could probably be economically obtained from the atmosphere by means of the Linde process.

According to O. N. Witt, the yield of the Birkeland-Eyde process is between 500 and 600 kilogrammes of anhydrous nitric acid per kilowatt year (820—970 lbs. per H.P. year); whilst, according to Edstrom,* a yield of 950 kilos per K.W. year has been reached with some furnaces.

* *Trans. Amer. Electrochem. Soc.* (1904), vol. vi, p. 25.

A new factory is now being built at Notodden which will receive power to the amount of 30,000 H.P. from falls at Svaelgfos, three miles distant. The furnaces will be of from 750 to 850 kilowatts each.

It is estimated by the company that the cost of production of calcium nitrate will be about £4 per ton, whereas the present selling price is £8. Power is at present rented from the Tinfos electric power station at 24s. per E.H.P. year, and from the new power station will be considerably cheaper.

In 1907, there was manufactured at Notodden 1,000 tons of saltpetre and calcium nitrate on the Birkeland-Eyde system. When the hydraulic power station which is to utilise the waters of the Tinfos Falls is completed, it will be possible to increase the annual output to 20,000 tons.

Another station, whose capacity will be 220,000 H.P., is in course of construction.

The commercial success of this process in Norway is very largely due to the efficiency and comparatively low first cost of the plant, and to the very cheap cost of power. The presence of easily-developed large water powers is making Norway a very promising centre for electro-chemical enterprises. On account of this, and also because of the general technical ability of the people, who have not been slow in availing themselves of their natural resources, it is to be expected that the electro-chemical industry will attain great importance in Norway.

Another method for the fixation of atmospheric nitrogen by electric discharges is that of Moscicki and Kowalski. This process has been installed at Vevey in Switzerland, a 2,100 H.P. plant having been in operation since 1903.*

* *Elektrotechnische Zeitschrift*, October 1906.
Electrochem. and Metall. Ind. (1907), vol. v, p. 491.

The arrangement finally adopted by Moscicki was that of a rotating arc. The arc flame is produced between two vertical concentric copper electrodes and rotated by magnetic lines of force parallel to the axis, spinning round in the annular space. Direct current is now used, applied at 1,500 volts or more.

The yield of this plant is 525 grammes of nitric acid per kilowatt year and only 1 per cent. of the energy is absorbed in the auxiliary apparatus.

Numerous other companies are engaged in the industrial manufacture of nitrates, notable amongst these being the "Badische Anilin and Soda Fabrik," which has independently carried out a vast amount of experimental work, and recently has come to an arrangement with the Norwegian company for the manufacture of nitrate on a large scale in Norway and elsewhere.

Cyanamide.

The problem of the fixation of atmospheric nitrogen has also been solved by a method totally different from the above. This is due to the discoveries of Frank and Caro which showed that calcium carbide acts as a good absorbent of pure nitrogen. By this means there is obtained a product known as calcium cyanamide which can be made to undergo several chemical changes forming compounds which readily yield ammonia, and other useful nitrogenous compounds. Calcium cyanamide undergoes such decompositions in the soil, and can therefore be employed directly as a fertiliser.

A development of the above process for preparing cyanamide was devised by Erlwein,* and adopted by Siemens and Halske, being manufactured according to this method by the Cyanidgesellschaft of Berlin and at the Badische Anilin and Soda Fabrik at Ludwigshaven

* *Elektrotechnische Zeitschrift* (1907), pp. 41, 62.
Elektrochem. and Metall. Ind. (1907), vol. v, p. 77.

and put on the market under the name of "lime nitrogen" (Kalk-Stickstoff).

The raw materials which serve as the starting point in Erlwein's method are coke and lime which are heated in a furnace after the type of the Acheson graphite furnace (p. 20), and over which nitrogen is passed. Absorption of the nitrogen and evolution of carbon monoxide takes place, yielding as a product calcium cyanamide.

When first brought out this process was more economical than that of Frank, starting with calcium carbide and nitrogen, on account of the high price of the former, but when the boom for carbide was over and prices went down, the Frank process became the cheaper one, and is now used in Italy and is being introduced into other countries.

Nitrogen can be obtained from the air by removing the oxygen with heated copper or else by liquefying air as in the Linde process and separating the nitrogen by distillation. On passing this through calcium carbide heated in closed gas-fired retorts, absorption readily takes place, and the carbide is transformed into cyanamide.

The cost of this manufacture depends of course upon the cost of separating nitrogen from the air, and on the cost of calcium carbide, which again depends on that of power. It is estimated that carbide factories which pay £2—£2. 10s. per H.P. year for power, and average prices for coke, lime, etc., and nitrogen, can make a good profit by preparing cyanamide to be sold as a substitute for saltpetre for fertilising purposes.

Besides being directly applicable as a fertiliser, calcium cyanamide has been applied to a number of other purposes, such as to the production of ammonium sulphate, the manufacture of dicyandiamide, a compound used in the manufacture of aniline colours and gunpowder. Cyanamide may also be used as a source of

sodium cyanide or potassium cyanide, according to a process devised by Freudenberg.

As a case-hardening material for iron and steel, calcium cyanamide has found a new sphere of application. This is due to the decomposition of the cyanamide giving up carbon to the iron which is thereby hardened.

For the manufacture of urea a small plant is already in operation in which the calcium cyanamide is treated in a suitable way with acids and immediately changed into a solution of urea which may be easily crystallised.

Works for the manufacture of cyanamide are now in operation, or in course of erection, at the following places:—

Place.	Present annual output. (Tons.)	In course of installation. (Output in Tons.)
Piano d'Orte (Italy)	4,000	6,000
San Marcel (Val d'Aosta)	—	4,000
Terni Carbide Works	—	10,000
Fiume	—	4,000
Almissa	—	10,000
France (two works)	4,000	—
Switzerland	3,750	—
Germany	12,500	—
Bavarian Alps	—	15,000
Canada	—	5,000
Japan	—	4,000
Odda (Norway)	12,500	50,000

CHAPTER XI.

POWER CENTRES AND ELECTRO-CHEMICAL WORKS IN GREAT BRITAIN.

THE question of the cheap generation of power—a matter of vital importance to the success of most electrochemical enterprises, is now receiving a favourable solution in this country. This is being brought about through the formation of large companies in various centres which generate electrical power in large stations and distribute to various works in their district. Generation of power on a large scale, in this manner, leads to considerable economy. Industries which are highly specialised also benefit largely by receiving power from an outside source, as greater concentration in management is thus possible.

In the production of cheap power and its wide application England is probably in more favourable circumstances than any other country, not even excluding those with water power. This is due to the abundance of good coal, and to the density of population and proximity of industrial centres to each other, thus enabling large power centres to distribute electric current over large areas with a minimum of transmission expenses.

The conditions in certain parts of Norway and the Alps are quite exceptional, and it cannot be expected that local power companies in this country will ever be able to supply current at the prices which are now prevailing in those districts. Indeed some of the prices for water

power in Norway and Sweden would not even pay interest on the capital cost of the necessary plant for steam power.

It is improbable, however, that the power prices in those countries represent permanent conditions; naturally the waterfalls first utilised were those which involved the least capital outlay, but as more powers are developed others must necessarily be harnessed with greater difficulty, and thus the price per H.P. year will rise. In this country, on the other hand, the price should show a downward and not an upward tendency with increased development. The cost of power in Norway and Sweden is certainly an extreme case. Comparing with water power in other countries, the price of power from steam in this country shows very favourably. It appears, for instance, that this is offered by at least one company in England as cheaply as at Niagara Falls. Apart from the cost of electrical power, all the other factors which determine the success of industries, such as convenience of transit and the proximity of the markets for finished products, are favourable to electro-chemical undertakings in this country.

Many schemes have been authorised by Parliament for the formation of large companies for supplying power within certain areas. In most cases the cost of production in a large and thoroughly up-to-date private plant would be considerably lower than the price at which the power company could afford to sell and distribute. Even in these cases, however, the desirability of a saving in capital and running charges in the early stages of an undertaking often makes it preferable to take power from the company.

The most prominent of the large power companies in this country at present is the Newcastle-upon-Tyne Electric Supply Co. Ltd., which now delivers power to various industries on the Tyneside and towns in the district.

NEWCASTLE-UPON-TYNE.

NEWCASTLE-UPON-TYNE ELECTRIC SUPPLY CO. LTD.*

This company, which is situated at the seat of the Northumbrian coalfields, is the first and most successful of its kind to engage in electric power distribution on a large scale in Great Britain. It began, in 1891, as an ordinary electric lighting company, and ten years later developed into a much larger undertaking, and began to furnish power for various industries on Tyneside.

The company has grown through accretion and expansion, has amalgamated with surrounding power companies, notably with the County of Durham Electric Power Supply Company, and taken over other smaller stations, in some cases using them as sub-stations. Newcastle has always been characterised by having its electrical supplies in the hands of companies, instead of, as is almost invariably the case with other provincial towns, being in the hands of the municipality. The manufacturing area around Newcastle now receiving power from this company includes Gateshead, Wallsend, and Tynemouth.

The principal generating station of this company is the Carville Power House which was built in 1904. This is situated on the banks of the Tyne, the site having a frontage of 420 feet which enables an ample supply of condensing water to be obtained. The station is laid out on what is known as the complete unit system, each of the larger turbo-alternators having its own condenser, exciter, set of boilers, pumps, etc., though sharing with another large set a common boiler house, coal bunker, chimney, and branch railway siding. A sub-division into what is practically speaking a number of independent stations is thus brought about, the only points of junction common to all the units being the main electrical bus bars, the circulating water system, and the main railway

* C. H. Merz and W. McLellan. *The Electrician*, July 1904.

siding. In this way security of supply is made more certain, as the effects of failure in any part of the machinery are confined to one unit. The use of this arrangement also enables extensions to be made without interfering with the symmetry of the station. The present equipment at Carville consists of two 3,000 H.P. and about six 7,000 H.P. turbo alternators. The alternators work at 1,200 revolutions and generate three-phase current at 40 cycles and 5,750 volts. The steam turbines possess a capacity for large overload of as much as 100 per cent. A load factor of over 50 per cent. in the consumption of the current is obtained.

The next station in importance belonging to the Newcastle Electric Supply Co. is at Neptune Bank. This has been in operation since 1903.

Distributing System.

The system of distribution has grown hand in hand with the enlargement of the means of generation, and a network of mains extends from North Shields on the east as far as Elswick on the west, and will soon reach as far south as Middlesborough. Current is transmitted from the generating station at a pressure of about 6,000 volts through paper-insulated, lead-covered, cables to sub-stations where it is either converted into direct current at low tension or is transformed to a pressure suitable for the consumer's use.

The largest consumers are Armstrong, Whitworth and Co., who take about 7,000 H.P., the North-Eastern Railway Co., the Tyneside Tramways and Tramroads Co., the North-Eastern Marine Engineering Co., Swan, Hunter and Wigham, Richardson and Co., Northumberland Shipbuilding Co., Castner Kellner Alkali Co., etc.

The price charged for current is 3¾d. per unit for lighting and 1½d. to ¾d. per unit for power though, of course, special terms are made to large consumers.

The development of large centralised electric power

supplies in this way is of the greatest significance to industry. The smoke nuisance could, in this way, be completely eliminated. Cleanliness is also secured in the interiors of buildings where electric power, instead of steam power, is used.

The larger the scale on which power plants are installed the greater is the economy, and, in the Tyneside district, it is being realised by manufacturers that they can receive their power from the Power Company at a cheaper cost than by generating themselves. It is now generally admitted that electric power in engineering works of all kinds is superior to any other. Moreover, when current is purchased from a power company, the total cost is known precisely and the user buys it as he wants it, whereas if he instals a generating plant of his own, he must make it equal in capacity to his maximum demand, together with a certain reserve margin. In this case, more or less of the plant will be idle at intervals and interest charges mount up.

The fluctuations in demand of the consumers of power from a central station will tend more and more to equalise and dovetail the total demand as the area of consumption increases, and thus raise the load factor of the power station.

Special terms are of course made in each case to large users of power, but the following diagram (copied from *Electrical Industries and Investments,* March 28th, 1906) contains figures of output and cost of production, and shows the reduction of the latter with increase of the former.

Year,	Revenue from sale of current. £.	Average Revenue per unit sold. d.	Total costs per Unit sold. d.	Margin between Revenue and Total Cost. d.	Units Sold.
1901	22,484	2.10	1.05	1.05	2,562,000
1902	41,701	1.81	0.82	0.99	5,537,500
1903	62,368	1.66	0.85	0.81	9,033,000
1904	92,512	1.29	0.66	0.63	17,132,153
1905	122,438	0.96	0.56	0.41	30,378,000

Throughout this period a dividend of 8 per cent. has been paid on the capital, which then increased from £300,000 to £750,000. At the end of 1906, a total of 70,000 H.P. was being generated by the companies system, and the profits declared during 1906 amounted to £85,000. At the end of 1907, the output had risen to 92,764 H.P.

An electro-chemical centre is now developing at Newcastle-upon-Tyne in consequence of the facilities offered by the power company. The present electro-chemical companies who avail themselves of this power are the Castner Kellner Alkali Co., who have a plant capacity of some 5,000 K.W., which is now being extended to 8,000 K.W., the Aluminium Corporation who are now installing a plant capacity of 5,000 K.W., and lastly the Thermal Syndicate who at present only take a few hundred H.P.

The Thermal Syndicate.

This company engages in the electrical manufacture of Quartz Glass or Fused Silica. This is applied as a ware and formed into crucibles, tubes and other apparatus to be used in chemical work, in this manner it provides the most refractory of wares and furnishes apparatus capable of withstanding the most sudden changes of temperature.

This material has found a particularly useful application in the manufacture of evaporators for concentrating sulphuric acid and, for most purposes of this nature, forms an efficient substitute for platinum.

This manufacture is of special interest as an application of very high temperature obtained by electrical heating to a process requiring considerable refinements in manipulation, it has moreover achieved considerable success in making available a most valuable material at a relatively very low cost. The process employed was initiated by experimental work carried out in the electro-

chemical department of this University.* Pure white sand is fused to a pasty condition at a very high temperature, and then blown and moulded into the desired form. Heating is applied by passing a large current through carbon rods or plates which are embedded in the sand. The resulting Quartz Glass or Fused Silica is of a white semi-transparent nature.

There are a number of other important power centres in operation or in course of development in this country; two or three of these are mentioned below.

Lancashire Electric Power Company.

This company has received parliamentary rights for the supplying of power over the whole of Lancashire south of the River Ribble, except Liverpool, Bootle, Manchester, Salford, Stockport and part of Bolton. The generating station is situated near Radcliffe, where four 2,000 K.W. Curtis engines are in operation, and current is generated at 10,000 volts, three-phase 50 cycles. The largest consumers are the Acme Spinning Co. Ltd., which takes 1,100 K.W. and the Chloride Electric Company which takes 500 K.W. There are 19 sub-stations in operation where the current is stepped down to 400 volts, three-phase, or 500 volts continuous, for local distribution. Power is sold at ·45d. per unit plus an additional charge which is graded from £6 per K.W. year for quantities up to 100 K.W. to £3 for quantities above 500 K.W.

The Yorkshire Electric Power Co., which hitherto has been working at a loss, is now progressing very materially and supplies 3,000 K.W. A prospective consumer of power from here is a large calcium carbide works

* R. S. Hutton. "On the Fusion of Quartz in the Electric Furnace." *Manch. Lit. and Phil. Soc. Proc.*, January 1902. *Trans. American Electrochem Soc.* (1902), vol. ii, p. 105.

known as the Imperial Automatic Light Co. Ltd.* These works are to be erected at Thornhill, Yorkshire, and it is expected will commence early in 1908. The works, as at present designed, are capable of an output of from 2,200 to 2,500 tons of calcium carbide per year.

This company will also manufacture a special plant for the generation of acetylene, which they claim will furnish a 2,500 candle power flame for 1 hour at a cost of 4½d. The plant may also be used for producing the oxy-acetylene flame for welding purposes. The apparatus is said to be portable and clean and absolutely safe in its working. This plant should find considerable application in the illumination of railway stations and isolated buildings where electric current is not conveniently available.

The North Wales Electric Power and Traction Company is of considerable interest, as it utilises a large water power from Llyn Llydaw on Snowdon, North Wales. The head of water here available is 1,150 feet.

At present four generators are installed, each of 1,500 K.W. The current is generated and distributed at 10,000 volts, and at present is being supplied to neighbouring quarries and for railway traction. The price charged for this power at present varies from 1½d. to ⅞d. per unit. The Aluminium Corporation is now erecting a works to prepare aluminium, using the power from this company. This works is situated 13 miles from the power station.

The South Wales Electrical Power Distribution Co., situated in Monmouthshire, Glamorganshire and Carmarthenshire generates a total of 7,520 K.W., and supplies power to neighbouring collieries and metal works at a cost of from 5.3d. to .35d. per unit according to load factor, etc.

* *Electrochem. and Metall. Ind.* (1908), vol. vi, p. 125. *Electrical Engineering*, November 28th, 1907. *Electrician*, February 7th, 1908.

The North-Western Electricity and Power Gas Co.

This is an undertaking which has secured rights for supplying power in portions to Staffordshire, Derbyshire, Flintshire and Denbighshire. The general scheme includes the furnishing of Mond gas as well as electricity. It is contemplated to erect generating stations at Stone and Ruabon, each of 7,000 H.P. capacity.*

Electro-chemical Works in Great Britain.†

The manufacture of calcium carbide was begun at Foyers in October 1896.

The Willson patents were acquired by the Acetylene Illuminating Company in May 1895, who arranged with the British Aluminium Company for the use of a portion of their available power. As soon as calcium carbide received application in the generation of acetylene great interest was attracted to the substance, and it was thought that the use of this gas would cause serious competition with coal gas and electricity as an illuminant. A very large number of companies were consequently formed for the manufacture of calcium carbide, and in the period from 1896—1899 as many as 650 patents were issued for its production.

For about three years the carbide industry enjoyed a period of prosperity and three or four factories were erected in England. Speculation in this field, moreover, was not limited to this country, as in the year 1899 there were 68 carbide factories in operation and 16 in course of construction in Europe. When the promises of acetylene were not realised, and the confidence of the public became shaken, this industry, in the years 1899 and 1900 underwent a very rapid decline, and the excessive overcapitalisation brought nearly every company into liquidation, or caused re-organisation.

* Supplement to *Electrician*, Jan. 3rd, 1908.

† J. B. C. Kershaw. "The electro-chemical and electro-metallurgical industry of Great Britain, 1907." J. B. C. Kershaw. *Electro-Metallurgy* (1908).

The Acetylene Illuminating Company were not able to maintain the Willson patents, and so the manufacture of calcium carbide was commenced by other companies, amongst these by the United Alkali Company at Liverpool. Apparently the only carbide works at present in operation in Great Britain is at Askeaton near Limerick, though a large plant is now being built in Yorkshire (page 122). At Askeaton use is made of a water power generating 400 H.P., and the furnaces have a capacity of 3,000 amps. at 100 volts. While the home production of calcium carbide cannot exceed 3,000 tons yearly, the consumption in Great Britain now amounts to a total of about 5,000, the whole of which is used exclusively for generating acetylene; none of the other proposed applications of this material having been successful.

Copper Refining.

The copper refining industry, which has now attained such dimensions, had its birth in this country. It is the oldest of all electro-metallurgical industries, dating from 1869.

J. Elkington, in 1865, began working on this subject, and from 1865 to 1869 a number of patents were taken out and a small factory was erected at Pembrey, in South Wales, for the electrolytic refining of copper. These works were subsequently enlarged and are still in operation to-day.

The second British Refinery was that of Bolton and Sons at Froghall, Staffordshire, and in 1880 a number of plants were erected in Swansea.

Copper from the American smelters was formerly shipped to England, France, and Germany to be refined, but is now all done on the East coast of America, in New Jersey. The high values of gold and silver are here extracted and only refined copper is exported to Europe. The English refineries consequently lost their chief

supplies of raw material, and since then have undergone little if any further development.

*Manufacture of Copper Tubes, Plates and Wire.**

In the usual arrangement for the electrolytic refining of copper, where use is made of a vat and stationary electrodes, copper is obtained in a more or less uneven or rough condition.

The unevenness of the metal increases with the current density and with the thickness of the deposit, so that smooth deposits cannot be obtained of any considerable thickness in the usual way.

The low current density which is needed very much prolongs the operation, and a considerable period of time is necessary, often 10—12 days, during which the metal is locked up in the vats, and a large amount of space and tank accommodation required. The current density employed in electrolytic refineries has been gradually increased from about 8 to 10 amperes to 20 amperes per square foot—16 to 17 amperes per square foot has usually been considered the limit with stationary electrodes. (See page 36.)

Various processes have been devised for increasing the current density by using mechanical means to prevent the copper from becoming rough. These different methods may be classified under the five headings.

1. Revolving or moving the cathode.
2. Burnishing the copper during deposition.
3. Insulating the excrescences or growths on the copper so as to prevent further increase.
4. Rapid circulation of the electrolyte.
5. Revolving the cathode at a high speed (centrifugal process).

* S. Cowper Coles. *Trans. Faraday Society*, August 1905, vol. i, p 215.

Class 2. A burnishing process was devised by Elmore and applied to the manufacture of copper tubes at a works founded at Hunslet near Leeds, in 1889. In this method an anode of crude copper is taken, and the cathode consists of a revolving mandrel of brass, which has been carefully coated with graphite, and on this the copper is deposited electrolytically. A burnisher of agate passes continually backwards and forwards, leaving the metal with a smooth and well polished surface. The usual current density is under 20 amperes per square foot, and the voltage between the electrodes from .5 to 1 volt. A 4-inch mandrel is revolved at about 30 revolutions per minute. When sufficiently thick, the tube is detached from the mandrel. Besides tubes, calico printing cylinders, paper machine cylinders and other special parts of machines of pure copper are manufactured here.

Class 3. Insulating the excrescences or growths on the depositing tubes is the principle devised by Dumoulin in a process in which a sheepskin burnisher is substituted for an agate one. The sheepskin impregnators, which move over the surface of the metal, coat all projecting parts with a thin film of animal fat, which hinders further deposition until the surrounding depressions have been raised to the common level. The current used in this process is from 35 to 40 amperes per square foot of cathode area, the voltage required is about 1·6 per vat. This process was worked for some time on a very large scale at the works of the Electrical Copper Co. in Widnes. The tubes prepared by this process were cut open and rolled into flat sheets of the approximate size 12 feet by 4 feet.

Class 5. A centrifugal process of copper deposition has been developed by S. Cowper-Coles, who found that if the mandrel constituting the cathode was revolved at a

certain circumferential speed, smooth thick deposits of copper resulted, with very high current densities which could not be obtained by any other method. A very pure copper is obtained in this way. Particles of impurities, which, in the stationary process tend to settle on the cathode and become enclosed, are repelled by the centrifugal action in this process. The composition of the electrolyte usually employed is—copper sulphate 10 per cent., sulphuric acid 10 per cent., water 80 per cent. A current density of from 80 to 275 amperes per square foot is used, the voltage varying from ·3 to 1·2 over this range.

Preparation of Copper Wire.

Various processes have been attempted from time to time for the production of copper wire by electrolytic means; very few of these have met with any success, however, on account of the difficulties of the problem. A satisfactory method designed by Cowper-Coles and employed in conjunction with the centrifugal process consists in making a spiral scratch on the mandrel. The effect of this scratch, which must be angular, is to affect the molecular structure of the copper and to form a cleavage plane. The copper is separated from the mandrel by unwinding at an angle to the axis of the latter. Three or four miles of wire can be made in a few hours from crude copper in one operation. For this purpose, an annular vat is used and a cylindrical mandrel 7 feet in diameter, arranged vertically, and making about 50 revolutions per minute. The great advantage of such a vat is that there are no working parts in the electrolyte and no stuffing boxes or glands are used.

The capital expenditure on the plant required for the centrifugal process is said to compare very favourably with that of an up-to-date rolling mill and wire-drawing plant of similar size.

Broughton Copper Works, Ditton, near Widnes.

The smelting of various copper ores and spent pyrites is engaged in here. The ores are imported chiefly from Spain and South America. A special variety of ore imported from Spain is atacamite, or copper oxychloride. This is brought into solution by treating with sulphuric acid and then decanting. Copper is removed from this liquid by the addition of scrap iron, and thus obtained in the form of powder. Silicate and sulphide ores of copper are treated in blast furnaces in the usual way.* The furnace charge consists of coke, and a mixture of ores in such a proportion as to give the necessary lime, silica and sulphur content. Slag from the reverberatory furnace treatment, which takes place at a later stage, and which contains about 10 per cent. copper, is also added, and flue dust which is made into a paste with lime. This smelting process is continuous, and the slag and matte are drawn off at the bottom. The former contains about ·3 per cent. copper and is thrown away, and the latter about 30 per cent. copper. This matte is smelted again and converted into high grade matte which contains from 50 to 60 per cent. copper, while the slag with a copper content of about 2 per cent. is added to the charge in the first furnace. The further refining of the high grade matte is then carried out in a reverberatory furnace at a very high temperature, whereby "white metal" is obtained. Air is then admitted in the necessary quantities, when conversion into "blister copper" takes place, which is then run from the furnace and cast into moulds. The final refining of this metal is then carried out either by melting and subjecting to a "poling" process, or else by casting into electrodes and refining electrolytically. The electrolytic process consists of a combination of the multiple and bipolar electrode systems. Anode and cathode are arranged in multiple in each vat, and in

* *Vide* page 53.

between each are placed two bipolar electrodes which are insulated from the leads and which receive a deposit of copper on one side and are dissolved on the other. Before use, these electrodes are coated with a thin layer of soot on the cathode side to facilitate the stripping off of the deposited copper. The 24 tanks are arranged in series on a sloping floor to allow free circulation of the electrolyte, and the difficulty of excess of copper tending to accumulate is got over by diluting the electrolyte and adding more acid. The excess of electrolyte thus produced is used in the leaching of the atacamite ore described above. A temperature of about 110°F. is used for the electrolysis. Current is supplied at 25 volts, and to the amount of 1,000 ampères, to the whole system. A voltage of ·2 to ·3 thus occurs between each electrode, and a current density of 12 amps. per square foot is used. The object of the combined multiple and series arrangement is to avoid the occurrence of a greater potential difference than 1 volt between the two ends of the lead-lined vats, as short circuit would otherwise result, and the lead lining cannot conveniently be replaced. The electrolyte contains about 13 per cent. copper sulphate, 3 per cent. sulphuric acid and a trace of glue to cause smoothness of deposit. The copper anodes remain in the bath about 30 days. The slimes, which contain antimony, silver, gold and impurities from the metal accumulate on the bottom of the vats and are removed and sold to metal refiners. Copper containing any appreciable amount of gold or silver is treated electrolytically, while that free from these metals is refined by the fire process.

*Electrolytic Lead Refining at the Smelting Works of Messrs. Locke, Blackett and Co. Ltd., Newcastle-on-Tyne.**

Lead is imported here and refined by two different processes—that of Parkes and the Betts process. This

* *Vide* page 57.

latter is, at present, on a comparatively small scale. The current is generated by means of gas engines and dynamos working at 30 volts. The anodes are larger than those in use at Trail, and are formed by pouring the metal in a shallow mould laid level on the ground. The anodes obtained by this method are far less even than with the Truswell mould; and consequently do not dissolve so well in the electrolyte, hence a larger proportion of metal is returned as anode scrap.

The starting sheets are formed by a process of W. Valentine, in which the lead is allowed to flow over an inclined iron plate which is provided with ridges along the edges and which terminates in a mould at the bottom which furnishes two projecting lugs on the sheet for the purpose of wrapping around the cathode bars. The anodes are 33 inches wide and 34 inches deep. A current density of 10–12 ampères only is used and an electrolyte containing 8 grams of lead per 100 c.c.

The slimes obtained are freed from electrolyte by washing and then treating in a filter press. The dried slime is then roasted and antimony removed as a lead antimony slag, and the remaining gold and silver separated by roasting and cupellation.

With regard to the relative merits of the two refining processes, it is found at this smelting works that for rich bullion the Betts process is the more economical, whereas for the refining of lead with low values the advantage lies with the Parkes process.

REFERENCE.—A. G. Betts. "Lead Refining by Electrolysis." 1908.

The Electrolytic Alkali and Chlorine Industry.

For half a century alkali and bleaching powder have been the leading products of England's chemical industry. The starting point for these substances is common salt. In the early part of last century it was observed that a solution of salt underwent decomposition

into alkali and chlorine under the influence of the electric current, and towards the end of the eighties the possibility of applying this method on an industrial scale began to receive a good deal of attention.

In 1851, C. Watt was granted a patent on a process for preparing caustic soda and chlorine by the electrolysis of salt, but chiefly through lack of a cheap source of electric power, this scheme was not carried further. In the electrolysis of salt great difficulty was encountered through the intermingling of the products of decomposition. Complications are introduced through the inter-diffusion of the alkali which, together with hydrogen, forms at the cathode and the chlorine which is liberated at the anode. In this manner hypochlorite and chlorate are also formed, according to the conditions of temperature and current density. Means had consequently to be adopted to separate the anode and cathode compartments.

From the year 1888, much experimenting was done on this subject and a large number of apparatus patented.

A process of Richardson and Holland was exploited at St. Helens in 1895, a plant of 1,100 H.P. being used. This did not prove successful, however, and the company subsequently went into liquidation, the machinery being sold in 1904.

Castner-Kellner Electrolytic Alkali Co. Ltd.

This process was protected by several patents taken out by Castner and Kellner during 1892 and 1893, and is characterised by the use of a mercury cathode or intermediate electrode. The sodium ions of the salt, on giving up their electric charge combine with the mercury forming an alloy, which is subsequently decomposed in another compartment by contact with water, thus giving rise to pure caustic soda and liberating mercury. In this way the mercury is used continuously. A very

slight rocking motion is imparted to the cell, causing the mercury to flow from one compartment into the other. A partition between the two compartments which extends into a slight trough at the bottom, forms an effective seal, keeping the salt solution separated from the pure caustic of the cathode chamber.

A works for carrying out this process was erected at Weston Point, near Runcorn, where at present about 4,000 H.P. is consumed. A Mond gas power plant in conjunction with large gas engines has recently been installed, and is now in use for the greater part of this power.

Castner Sodium Process.

The Castner-Kellner Electrolytic Alkali Company operates a plant for the production of sodium from fused caustic soda. This process was first carried out at the main works at Weston Point, but when enlargements were found necessary, it was decided to remove this department from Runcorn and to establish it on the Tyne in order to take advantage of power offered them by the Newcastle Company (page 120) without themselves going to any further expenditure for power generation. This change proved a great advantage to them as it liberated a large amount of power which they were able to use in other branches of manufacture.

The works at Newcastle is situated on ground adjoining that of the Carville Power Station, and possesses its own sub-station where current is received at 6,000 volts, three-phase alternating. This is stepped down to about 160 volts by means of static air-cooled transformers, and then by means of motor generators and rotary converters changed into direct current at 250 volts. A total of about 5,000 K.W. is now taken from the Power Company, and extensions are said to be in progress which will raise this to 8,000 K.W.

Hargreaves-Bird Process at Middlewich, Cheshire.

This was brought out in 1892, and an experimental plant was erected at Farnmouth.

In this process the separation of the alkali and chlorine is achieved by the use of a diaphragm formed from a composition of asbestos and sodium silicate. This diaphragm forms the walls of the anode chamber, and retains the salt solution, whilst allowing the ions to pass through, under the influence of the current. The cathode of copper gauze is placed against the diaphragm outside the anode chamber, and steam and carbon dioxide are passed through the cathode compartment, thus forming sodium carbonate with the sodium liberated at the cathode. This works is installed at Middlewich, Cheshire, directly over an extensive brine deposit. The brine is for this purpose, pumped and used directly in the cells without any particular treatment.

About 115 tons of salt per week are decomposed in this manner and a yield of 150 tons bleaching powder obtained.

The Hargreaves-Bird cell is also in use at the plant of the West Virginian Pulp and Paper Company at Piedmont, W.Va.,* and at Mechanicville, Pa. At the former works there are 16 cells installed, each of which produces chlorine equivalent to 460 lbs. of 35 per cent. bleaching powder per 24 hours.

The total electrical horse power used for the electrolysis is 200. The cost of a cell of this size, including royalty in Great Britain, is said to be about £200.

Aluminium Industry.†

The first aluminium works in this country was established at Milton, Staffordshire, by an American

* *Engineering and Mining Journal* (1907), vol. lxxxiii, p. 137.

† Compare page 26.

Company, to exploit the process of the Cowles Brothers. Until 1892 aluminium alloys were prepared here by an electric furnace in which the action of the current was purely a thermal one (page 26). This method replaced all the existing chemical processes for preparing aluminium alloys and led to their being applied in industry.

In 1886–1887, Héroult in France, and Hall in the States, independently brought out electrolytic processes for aluminium which gave the pure metal in distinction to the alloys obtained by the above methods. These two processes are practically identical and consist in the electrolysis of alumina dissolved in fused cryolite. Since 1891 this has been the sole method by which aluminium has been prepared.

From 1885 to 1906, the price of aluminium gradually fell from £2. 5s. a lb. to about 1s. 2d., while the world's annual production rose from 3 tons to about 1,500 tons in the same interval.

The production of aluminium in 1906 has been estimated by J. W. Richards to amount to nearly 19,500 tons, valued at £2,500,000. An estimate made by the Metallurgische Gesellschaft for the same period is as follows:—

United States	6,000 tons.
Germany, Austria and Switzerland	3,500 tons.
France	4,000 tons.
England and Norway	1,000 tons.
	14,500 tons.

The world's output of aluminium in 1907, probably approached 20,500 tons (*Electrician,* March 27th, 1908).

* *Engineering and Mining Journal,* vol. lxxxiii, p. 1083.

British Aluminium Company.

The works at Milton, of the Cowles Syndicate was afterwards taken over by the British Aluminium Co., which began operations in 1896, and erected their principal works at Foyers in Scotland. Use is here made of a water power between Foyers River and Loch Ness, a head of over 300 feet being obtained and a total of 6,000 H. P. being generated. Alumina, in the form of bauxite is obtained from deposits in Ireland, and is refined at the works at Larne.

The metal is sent from Foyers to Milton to be refined and cast into bars or made into sheets.

About 12 E.H.P. hours are needed to produce each pound of aluminium.

*Kinlochleven Works.**

The Falls of Foyers have been fully utilised by the British Aluminium Company, and on account of the need of further extensions, a scheme for a large hydraulic development, near Loch Leven is being undertaken. A reservoir is being constructed in a large basin situated 1,000 feet above sea level, and only about 5 miles distant from the coast. The capacity of the reservoir will be about 20,000 million gallons. For the formation of this a dam is being constructed which will be over half a mile in length, and a maximum height in the middle of 80 feet. The water will be led through a concrete conduit along the hill face for a distance of about 3½ miles, to the head of the pipe line. The head of water at the turbines is stated to be 900 feet and the total power available will be about 60,000 H.P. The cost of the undertaking will be about £500,000, and it is expected that the process will be started by the summer of 1909. Two thousand men have been continuously employed at this work during 1907.

* *Electrician*, August 31st, 1906, p. 764: March 27th, 1908, p. 907.

Another factory belonging to this company is now in operation in Norway at Stangfjord. The British Aluminium Company at their annual meeting in June, 1907, showed a balance, available for interest and dividend purposes of £158,903.

The Aluminium Corporation.

This is a company which was formed during 1907, with a capital of £500,000 to engage in the manufacture of aluminium. A works is being erected on Lake Eigiau near Conway, in North Wales, where 4,400 H.P. will ultimately be developed from water power. Arrangements have also been made for the supply of 1,600 H.P. from the North Wales Electric Power Company.

Another branch of this works is being erected at Newcastle-on-Tyne (page 120) on a plot of land adjoining the works of the Electric Supply Company from which 4,000 K.W. will be taken.

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